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Participatory Design in Museums

Visitor-Oriented Perspectives on Exhibition Design

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Avhandling som med tillstånd av Kungliga Tekniska högskolan
framlägges till offentlig granskning för avläggande av filosofie doktorsexamen
fredagen den 3 juni 2005 kl 10.00
i sal E1, Lindstedtsvägen 3,
Kungliga Tekniska högskolan, Stockholm.

TRITA-NA-0516
ISSN-0348-2952
ISRN-KTH/NA/R--05/16--SE
ISBN 91-7178-082-3

Cover photograph: The Museum of Science and Technology, Stockholm.

Abstract

This thesis is about the design of technology for museum exhibitions. More specifically, it explores different ways in which visitors can contribute to museum exhibition design and how technology can support learning-related activities within museum exhibitions.

Most contemporary museums collect, preserve, and provide access to important cultural and historical artefacts with the explicit intention of educating and informing the general public about those artefacts. For many exhibition designers, the audience's encounter with the exhibition is of primary concern, and technology is often seen as a means for providing visitors with new experiences and opportunities for learning. However, it appears to be only very recently that researchers have begun to show an interest in how modern technology *is actually being used by visitors* and many museums are struggling in their efforts to incorporate new technologies in their established exhibition design practices.

Thus, on the one hand, many museums are seeking more visitor-focused ways of carrying out design (with the help of, for example, different forms of evaluation or feedback). On the other hand, many museums seem to have limited experience with designing technology in a user-oriented fashion. Consequently, human-computer interaction, with its long tradition of involving users in design, is in a position to provide museums with *new ways for audiences to contribute to exhibitions with their knowledge, experience, opinions, and desires*. The papers in this thesis explore this topic through a number of case studies where visitors have been invited to contribute to the design and evaluation of exhibitions. The analysis of the results suggests that visitors can provide relevant contributions in all of the main phases of museum exhibition production.

This thesis also addresses the issue of *how technology can support learning-related activities in museums*. It appears that many museums base their notion of learning on epistemologies which suggest that activities such as interpretation, communication, and collaboration are fundamental to most museum learning processes. Consequently, the papers in this thesis explore a number of different techniques for supporting and orchestrating such social activities. The result is a set of design approaches that has the ability to encourage collaboration and dialogue between co-present visitors and allow visitors to create dynamic and evolving contexts for existing exhibits.

In summary, the contributions of this thesis explore museum exhibition design from two different, yet interrelated perspectives. From the first perspective, visitors' desires, wishes, experiences, and knowledge are seen as important contributions to museum exhibition design. From the second perspective, different social activities and relationships between visitors in museums become the focus of the design activities. Together, these two

perspectives outline an approach to museum exhibition design where *visitors are of primary concern*, both with respect to the content presented in exhibitions and with respect to the way exhibitions orchestrate and support different forms of social interaction.

Acknowledgements

The conventions that dictate what a doctorial thesis should be like emphasize personal contribution to a very large extent. That is, the doctorial thesis should be concerned with *my* work, the knowledge *I* have developed as a result of the work, and *my* interpretation of that knowledge. This has made the writing of this thesis a rather tricky business because in my experience, research is not carried out only by individuals. Nor do individuals develop new knowledge on their own. Rather, science appears to be something that evolves from complex (and wonderfully fascinating) social relationships between human beings. Insights and discoveries are rarely (if ever) "made" by any one person, but tend to originate in situations where people communicate, ranging from lively discussions at research conferences to quiet talks over a cup of tea in the lunch room.

Writing an acknowledgements section that does justice to all the incredible persons who have contributed – directly and indirectly – to the work described in this thesis is an impossible task. Nevertheless, I would still like to thank a number of persons without whose support this thesis would have been quite impossible to complete:

Yngve Sundblad, *Lars Taxén* and *John Bowers*
for their careful and insightful supervision.

Sten-Olof Hellström and *Helena Tobiasson*
for their wonderful and inspiring contributions to the exhibits and exhibitions we have put together over the years.

Mariana Back at the Museum of Science and Technology,
Tore William-Olsson and *Elna Nord* at the Vasa Museum, and
Ulla Arnell at Swedish Travelling Exhibitions
for taking my strange exhibition design ideas seriously and for helping me realizing them in practice.

Eva Persson, *Hanna Wärff-Radhe* and *Helen Vigil*
for challenging my prejudiced views of modern art and artistry.

Pär Bäckström and *Olle Sundblad*
for being fantastic room mates.

Allison Druin and *Ben Bederson*
for teaching me how to *listen* to children.

Maria Engström
for her competent assistance in matters of printing and photography.

Björn Thuresson and the rest of "the gang" at CID
for creating a reflective, inspiring (and challenging!) environment where amazing things appear to happen every day.

Sture Nyman
for helping me get a grip.

Colleagues working in the numerous projects I have been involved with for their insights, inspiration and guidance.

All users, visitors and other "ordinary" people I have had the privilege of working with over the years for their patient participation.

Eva, *Anna*, *Erik*, *Kerstin*, *Lasse*, *Tina* and *Riitta*
for being who you are!

The research described in this thesis has been funded by the Swedish Agency for Innovation Systems, the European Union, the Swedish Foundation for Strategic Research, the Royal Institute of Technology, the Museum of Science and Technology, the Swedish National Maritime Museums, and Swedish Travelling Exhibitions.

In Memoriam

Sören Lenman (1947-2004)

Inger Isaksson (1946-1984)

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List of publications

Papers included in this thesis:

A. Taxén, G., Druin, A., Fast C., and Kjellin, M. KidStory: a technology design partnership with children. *Behaviour & Information Technology,* 20(2), 119–125.
B. Taxén, G. Introducing Participatory Design in Museums. In *Proceedings of the 8th Biennal Participatory Design Conference (PDC 2004)*, 204–213.
C. Taxén, G., Hellström, S.-O., Tobiasson, H., Back, M., and Bowers, J. The Well of Inventions - Learning, Interaction and Participatory Design in Museum Installations. In *Proceedings of the Seventh International Cultural Heritage Informatics Meeting (ICHIM 2003)*. CD-ROM Proceedings.
D. Taxén, G. Teaching computer graphics constructively. *Computers & Graphics*, 28(3), 393–399.
E. Taxén, G., Bowers, J., Hellström, S.-O., and Tobiasson, H. Designing Mixed Media Artefacts for Public Settings. In Darses, F., Dieng, R., Simone, C., and Zacklad, M. (Eds.) *Cooperative Systems Design. Scenario-Based Design of Collaborative Systems.* Amsterdam: IOS Press, 2004, 195–210.
F. Taxén, G., and Frécon, E. The Extended Museum Visit: Documenting and Exhibiting Post-visit Learning Experiences. In Trant, J. and Bearman, D. (eds.). *Museums and the Web 2005: Proceedings*, Toronto: Archives & Museum Informatics. CD-ROM Proceedings.

The papers will be referred to by the letters listed above.

Other related publications:

- Fraser, M., Bowers, J., Brundell, P., O'Malley, C., Reeves, S., Benford, S., Ciolfi, L., Ferris, K., Gallagher, P., Hall, T., Bannon, L., Taxén, G., and Hellström, S-O. Re-tracing the Past: Mixing Realities in Museum Settings. In *Proceedings of the First ACM Conference on Advances in Computer Entertainment (ACE 2004)*, April 2004.
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- Fraser M., Stanton, D., Ng, K. H., Benford, S., O'Malley, C., Bowers, J., Taxén, G., Ferris, K., Hindmarsh, J. Assembling History: Achieving Coherent Experiences with Diverse Technologies. In *Proceedings of the 8th European Conference of Computer-supported Cooperative Work (ECSCW '03)*, 179–198.
- Hourcade, J.P., Bederson, B.B., Druin, A., Taxén, G. KidPad: Collaborative Storytelling for Children. In *ACM 2002 Extended Abstracts on Human Factors in Computing Systems (CHI '02)*, 500–501.
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- Taxén, G. *Towards Living Exhibitions*. Licentiate thesis in human-computer interaction. TRITA-NA-0311, Department of Numerical Analysis and Computing Science, The Royal Institute of Technology, Stockholm. May, 2003.

1. Introduction

Museums

The word *museum* originates from the Greek word *mouseion*, which translates into "house of the muses", that is, the temple of the nine Greek goddesses who gave artists their inspiration. The first *mouseion* was built in Alexandria around 300 B. C. and was primarily used as a research institution and knowledge centre where researchers of various disciplines could live, meet, study and work. In Greek and Roman societies, pieces of art and other items were often put on display in public environments such as baths, theatres and forums. However, during the Middle Ages, artefacts were increasingly collected and kept by religious institutions.

In the mid-15th century, Italian nobles began to collect artworks from ancient Greece and Rome and put them on display, mainly in order to rise in social position. As a result, a new interest in these cultures arose (Hooper-Greenhill, 1992). One of the most well-known banker families, the Medicis, built a famous palace in Florence. The Medici palace housed not only a treasure in precious metals and stones but also Greek and Roman items that the family had collected. The family also commissioned artwork from architects, painters, and decorators to furnish the building itself. The palace was not open to the public – rather, the merchant prince personally invited visitors.

In the 17th century, collections of items from around the world were rather abundant in Europe. The way of displaying them became different, however: the function of the displays changed from a means of advancing the owner's social position to exhibitions with an encyclopaedic goal. Some collections were kept for teaching purposes by individual researchers at universities, but many were put together to represent the owners' view of the world (ibid.). A classic example of these kinds of displays is the *Wunderkammer* or the "cabinets of curiosities". Such cabinets typically had numerous compartments (of which many typically were secret or required a special procedure to open) that held items of varying types. For political reasons, such cabinets evolved into *Kunstkammers*, that is, large indoor spaces to hold art and curious artefacts, and were sometimes built specifically for the purpose of hosting ambassadors and other important visitors. The development of palace gardens can, in turn, be seen as an extension of the Kunstkammer concept.

In the mid-17th century, the *Royal Society* was formed in England. One of its aims was to standardise language among tradesmen, scientists, and the church. To support this process, the Society assembled a collection of items, known as its *Repository*, to represent this standardised language. By arranging for an institution to own the collection rather than a private individual, it was hoped that the Repository would stand a better chance of surviving and growing than private collections, which tended to disperse at the death of the owner. Because the Repository was formed with the intention of providing opportunities for study, the motivation for assembling complete collections was high. The Royal Society also appointed a *curator* to manage the laboratory that was made available in connection with the collection (ibid.). Not surprisingly, perhaps, the cataloguing attempt failed. At this time, there was no standardized way of classifying specimens, and the Society lacked the funds necessary for pursuing its goals. Also, the collection was only available to the members of the Society, of which only a few were scholars. Today, the Repository is a part of the British Museum.

In France, after the revolution, the collections of the aristocracy were appropriated in the name of the new Republic, gathered together, reorganized, and transformed. The aim was to make the collections available to all citizens of the Republic. Another reason for organizing this new type of museum was to display the decadence and forms of control of the old regime and to present the democratic values of the new. A similar perspective was gradually adopted throughout the rest of Europe (ibid.).

It is often claimed that the concept of the public museum as we know it today evolved during a period between the late 18th and late 19th centuries. The formation of the modern museum was influenced by a number of other cultural institutions, such as libraries, public parks, and fairs (Bennett, 1995). The onset of the Enlightenment and, later, Modernism prompted the museum to become a part of a larger system of cultural and governmental organisations and schemes for educating the "common man" (ibid., pp. 19–25). The initial aim was to attempt to regulate behaviour, which would allow government to "act at a distance", so to speak, by endowing the public with capacities for self-regulation and self-monitoring. In particular, museums were charged with providing the means for elevating popular taste and design. This required the museum to become more inviting and less socially exclusive. It also required the content matter to be reoriented from displays that merely evoked wonder and surprise towards displays that provided enlightenment. The design of the physical space of the exhibition was also targeted as a means for regulating aspects of conduct (for example, galleries were designed with the intention of providing calm and quiet spaces for contemplation and observation). This required museum collections to be rearranged according to the principle of *representativeness* rather than rarity. Displays and exhibitions designed to provide evolutionary and historical accounts became more frequent, and classification gradually became an important organising principle (ibid, pp. 33–35). Although the governmental goals related to regulation would probably be rejected by most museum institutions today, the museum is still considered an important tool for educating the public.

Museum exhibition design

Thus, most contemporary museums are concerned with collecting, preserving, and providing access to important cultural and historical artefacts with the explicit intention of educating and informing the general public about those artefacts. The curator role remains extremely important. Curators often plan and oversee the arrangement, cataloguing, and exhibition of the museum's collections and, along with technicians and conservators, maintain the collections (Lord & Lord, 2002). They are frequently expected to coordinate educational and public outreach programs, such as tours, workshops, lectures, and classes, and may work with the boards of institutions to administer plans and policies. Additionally, they may research topics or items relevant to their collections.

Historically, the curator often single-handedly designed exhibitions. Today, most museum design teams also include educators, designers, artists, carpenters, technicians, and maintenance staff. New exhibition projects typically begin with a *conceptual phase* in which a subject and a visitor target group are selected. After the design team has generated a number of ideas, available resources for completing the project are assessed, together with the reservation of a suitable time slot in the exhibition schedule. A *development phase* follows in which funding is acquired and the physical and educational design of the exhibition is completed. The time period when the exhibition is on display is often referred to as the *functional phase*. In this phase, educational programs are implemented and the exhibition is typically also presented to the public through pre-scheduled guided tours. It also includes personnel administration and maintenance work, and ends with the dismantling of the exhibition and the balancing of accounts. In the functional phase, evaluation is often used to determine whether the exhibition has met its goals. Many evaluation methodologies exist, including questionnaire surveys, in-depth interviews, structured and semi-structured interviews, and behavioural observation (Binks & Uzzell, 1994). Often, several of these evaluation methodologies are combined to triangulate the findings and strengthen the conclusions of the data analysis. The production cycle ends with an *assessment phase* where the where the process itself of developing exhibitions is evaluated. The outcome is a number of suggested improvements to the production process and ideas for future exhibitions.

Learning in museums

During the last few decades, a growing number of researchers within the museum domain have argued for a shift in focus in exhibition design from the curator or the subject specialist towards the educator and the evaluator (e.g., Screven, 1993; Hooper-Greenhill, 1994; Hein, 1998). As a result, learning and evaluation of learning is becoming increasingly more important in the production of museum exhibitions. This growth in interest in exhibition evaluation is one of the underlying reasons for the formation of the *museum visitor studies* research area, which builds on theory from sociology, psychology, education, marketing, management, and leisure studies. It covers subjects such as demographics, data on attendance, psychological profiling, patterns of visitor behaviour, and the development of educational assessment methodologies (see, e.g., Hein, 1998 for a more in-depth account).

It appears that many designers of museum exhibitions are influenced by a number of interrelated epistemological philosophies that are collectively referred to as *constructivism* (Kukla, 2000; Twomey Fosnot, 1996; von Glasersfeld, 1995; Ernest, 1998; Rogoff, 1990; Lave & Wenger, 1991). An overview of two influential epistemologies within constructivism is provided in Paper D. Historically, museum learning has often been thought of as a form of *transfer of knowledge*, that is, learners were seen as "decoders" of messages that had been "encoded" into the exhibition by the curator or the design team. In other words, if the exhibition was correctly designed and there was no "interference" during the visit, all visitors would, at least in theory, acquire the same knowledge from the exhibition (Hooper-Greenhill, 1994; pp. 28–43).

However, from a constructivist-oriented epistemological perspective, such a view of learning fails to capture the complex ways that knowledge acquired during the visit is shaped by later events (Falk & Dierking, 2000; pp. 3–13). Nor does it take into account the way that previous knowledge, interests, and the museum experience itself – including interaction with other visitors – shape the learning outcome (ibid., Hooper-Greenhill, 1994; Hein, 1998). Indeed, many museum educators are arguing that focusing on individual exhibitions may not be enough to fully account for learning in museums (Hooper-Greenhill, 1994; pp. 40–42). Museums are institutions that are part of society and culture in general. The public image of the museum depends on the experience people have of it, and this image is shaped by numerous factors, including not only the exhibitions and the buildings in which they are situated, but also outreach events, orientation facilities, publications and practical issues like the availability and quality of shops, cafés and toilets. The public image of a museum in turn influences the number of visitors, the number of recurring visits, and by extension, ultimately the learning outcome.

Technology in museums

Many museums experiment with new technologies, ranging from devices for replaying video clips to massively interactive IMAX cinema presentations. These technologies are used to enhance, augment or replace traditional exhibition techniques (e.g., Broadbent and Marti, 1997; Burgard et al., 1999; Aoki et al., 2002; Oberlander et al., 1997), or even to "virtualise" parts of the museum and make them available on the Internet (Cutler, 2000; Rayward and Twidale, 1999). During the last decade, museum-related technology has become an established field with research being promoted in conferences such as the International Cultural Heritage Informatics Meeting (ICHIM) or Museums and the Web. Well-known journals of museum research also publish scholarly texts on technology (e.g., the special *Curator* issue on technology, 45(1), 2002). Most of this research, though, appears to be concerned with introducing new information technologies to the museum domain and experimenting with their possibilities and affordances.

Participatory design

The roots of the research area Human-Computer Interaction (HCI) can be traced back to the late 1960s, when a growing number of researchers became concerned about the ways in which humans interacted with computer systems. The need for "people-oriented" systems which reflected the needs and behavioural characteristics of users became a matter of major interest to the computing profession. Researchers in HCI studied *human factors in computing systems*, that is, the physical and psychological capabilities of humans, with a special focus on the way such factors come into play when humans interact with computer equipment. The rationale of most such research is that psychological experiments can increase understanding of the underlying principles of interaction between machines and humans (Schneiderman, 1998; pp. 28–29). The outcome is often guidelines for the design of computer interfaces or models of human performance in different task-based situations that involve computers (e.g., Card et al., 1980).

In the early 1970s, a new and partly opposing perspective on computing technology emerged from work within a number of Scandinavian research projects (Greenbaum and Kyng, 1991; Schuler and Namioka, 1993). The Scandinavian researchers tended to see most human factors research as problematic and claimed that it had a limited scope, which could lead to results that de-emphasised people's individual motivation, their membership in different communities of practice, and the importance of their work context. Rather, the Scandinavian researchers focused on the *ways in which new computer technology was being designed* just as much as on the specifics of the human-computer interface.

The first of these so-called *cooperative* design projects are often collectively referred to as the *Scandinavian tradition in computer systems design*. In the 1970s and 1980s, the Scandinavian countries had some distinctive features: they had high living standards, one of the highest educational levels in the world with full literacy, shared political traditions, similar socio-economic institutions, and a history of fairly intense and casual cooperation at all levels of society. In addition, they were open societies with an advanced technical infrastructure (Iivari and Lyytinen, 1998). This led to a lucrative environment for the exploitation of information technology. Furthermore, the level of unionisation was high and the national trade union federations held strong positions, in part because of their close connections to the large social democratic political parties but also because the relations between trade unions and employers were regulated by laws and central agreements.

For example, the Swedish Joint Regulation Act of 1977 stipulates that employers must negotiate with the local trade union before making major changes in production (Ehn, 1993). The introduction of new computer technologies intended to support the planning of work and make it more efficient often resulted in substantial modifications of the production process. Consequently, the unions became increasingly interested in management issues. However, up until that time, the activities of the unions had mainly involved distribution issues (for example, wages and working hours), and they therefore lacked the necessary competence to initiate discussions. Thus, the support of activity-oriented researchers was requested (ibid.).

When the simulation programming language *SIMULA* became available in 1965, it was immediately used in a number of companies in Norway and Sweden in the analysis of workplace processes. Kristen Nygaard, who designed *SIMULA* together with Ole-Johan Dahl, held the view that their tool was used to promote an unfair Tayloristic view of management. Consequently, he contacted the Norwegian Trade Unions with the aim of assisting them in developing an information technology policy (Nygaard, 1992). This led to a research project, initiated in 1972, that involved the Norwegian Computing Centre (where Nygaard worked) and the Norwegian Iron and Metal Workers' Union (NJMF). Initially, the aims of the project included the study of existing computer-based planning and control systems and assessing the goals of the union in areas such as work conditions and organization control. Other goals included the formulation of a set of demands for computer-based systems and the evaluation of the need for knowledge within the Union in areas of planning, control, and data processing (Ehn, 1993).

However, the realization that the outcome of the project, as originally conceived, would not directly benefit the Union necessitated a reformulation of the project goals towards a more action-oriented approach. In the new formulation, the project results were seen as actions carried out by the trade unions at local or national levels (Nygaard, 1992). Consequently, a small number of workplaces were selected, and an investigation group consisting of union members was formed at each of them. These groups were encouraged to accumulate knowledge about process control, to investigate problems of special importance to the local unions, and to take actions directed at management in order to change the way new technology was being introduced. The outcome of the NJMF project was a number of "data agreements" – both local and national – that regulated the design and introduction of computer-based systems and the availability of related information (Ehn, 1993).

The success of the NJMF project inspired a number of similar projects across Scandinavia, such as the four-year Swedish DEMOS project (Trade Unions, Industrial Democracy, and Computers). The project, which was initiated in 1975, aimed at identifying how the unions could influence the design and use of computer-based systems at local company levels (ibid.). However, projects like DEMOS and NJMF could only influence the way technology was being introduced to a certain degree. In particular, the technical limitations of the traditional systems advocated by management made it difficult to develop alternative, union-approved workplace organizations. Thus, a number of projects were initiated to support the design of completely new technologies.

One of the most influential of these was the UTOPIA project (Training, Technology, and Products from a Quality of Work Perspective) that was begun in 1981. The project was a collaboration between the Nordic Graphics Workers' Union, the Swedish National Institute for Working Life, and the Computer Science departments at Aarhus University and the Royal Institute of Technology in Stockholm. The primary goal of the project was to develop opportunities for workers to influence the design of computer-based workplace technologies, the rationale being that such an influence would have a positive outcome on the design. Thus, the project attempted to investigate how the then recently developed graphical workstation could support common tasks in the newspaper cutting room. The project group consisted of six graphics workers and about 15 researchers (Bødker et al., 1987; Bødker et al., 2000).

One of the main contributions of UTOPIA was its development of a "tools perspective" on computer systems design. From this perspective, new technology should be developed as an *extension of the current practical understanding of tools and materials at a given workplace*. Users were seen as having knowledge (often tacit) of how they go about their work, while often remaining unaware of the new possibilities offered by the introduction of new technology (Bødker et al., 1991). At the same time, the computer system designers, who do know the technology, often lack important knowledge about the workplace (Ehn, 1993). Consequently, UTOPIA attempted to initiate a process of *mutual learning* between designers and workers, which involved demonstrating existing state-of-the-art technologies to the workers and visiting workplaces where modern technology was being used. However, communication issues became increasingly problematic when the project moved on to the design of new systems. The reason was that the workers did not share the developers' concepts and language (for example, the use of data and information flow diagrams). As a result, a more concrete "design-by-doing" approach was adopted where the workers carried out hypothetical work scenarios using low-tech prototypes (for example, paper, cardboard boxes, and slide projectors) (Ehn and Kyng, 1991). The ensuing designs were then implemented as a prototype system, which was used for a time at *Aftonbladet* (a Swedish newspaper). For numerous reasons, the prototype was never developed into a marketable product (Bødker et al., 2000; Ehn 1993). From a methodological perspective, however, the UTOPIA project was a substantial success and it has spawned a number of similar projects, one of which is KidStory, which is described in Paper A.

During the late 1980s and early 1990s, the Scandinavian projects became more widely known within the field of HCI, which led to numerous attempts at implementing their methodologies under the name *participatory design* in the United States (Schuler and Namioka, 1993; Muller et al., 1993). However, because of differences in socio-economic structures (for example, the lower level of unionisation in the United States), the political aspects that were central to the original Scandinavian projects have been downplayed in their North American counterparts. Indeed, it is questionable whether the Scandinavian tradition has remained true to its original intentions of democratizing the workplace (e.g., Bansler and Kraft, 1994; Iivari and Lyytinen, 1998; Bødker et al., 2000). Furthermore, it seems that most of the Scandinavian projects have failed to achieve *sustainability*: when the researchers' involvement ended, most of the workplaces reverted to previous activities (Clement and Van den Besselaar, 1993). Thus, the most important contribution of the cooperative design movement appears to be *the introduction of a number of methodologies for involving users in design.* Although democratization is often an underlying philosophical ideal in many "second generation" projects, they tend to focus more on the development of efficient prototyping or work analysis techniques rather than on workplace reorganization (e.g., Crane, 1993; Floyd, 1993; Bennett and Karat, 1994; Muller, 1993; Muller, 2001). A notable exception is the UsersAward project, which involves users in the design of tools for organising work (Walldius et al., 2004).

In summary, cooperative and participatory design research is typically concerned with different issues than traditional human factors research (Bannon, 1991). More specifically, cooperative and participatory design research tends to

- Focus on workplace group dynamics rather than on individuals using the computer in isolation.
- Acquire knowledge about workplace organizations rather than conduct research from within the laboratory.
- Focus on expert users rather than on novices.
- Design new systems through iterative prototyping rather than analyse existing systems.
- Design *with* users rather than *for* users.
- Advocate the use of iterative prototyping as an alternative to user requirements specifications.

The work described in this thesis is more concerned with involving users in design than in bringing about sustainable change in organizations. Thus, I see it as a contribution to the field of participatory design rather than cooperative design, which is also reflected in the terminology I use.

Collaborations with exhibition producers

This thesis is largely concerned with different kinds of collaboration. Over the course of research the Centre for User-Oriented IT Design (CID), where the research was carried out, has collaborated with three different exhibition producers: the Museum of Science and Technology, the Vasa Museum, and Swedish Travelling Exhibitions. The research has mainly been funded by the Swedish Agency for Innovation Systems (VINNOVA) and the exhibition producers through so-called *industrial partnerships*. The goal of these partnerships is to allow organizations (both governmental and user/union organizations) and companies to collaborate with academia in projects that are of mutual benefit. Each partnership is regulated in a contract that describes the extent of the collaboration and the nature of the resource contribution from CID and the external partner. In this case, the exhibition producers have contributed mainly through work hours and funding, but also through, for example, exhibition space and work materials. CID has contributed with work hours, research results and artefacts in the form of exhibitions and exhibits. The following sections provide further details.

CID and the Museum of Science and Technology

The Museum of Science and Technology was founded in 1924 by the Royal Swedish Academy of Engineering Sciences, the Confederation of Swedish Enterprise, The Swedish Inventors' Association, and the Swedish Association of Graduate Engineers as a means for preserving Sweden's technical and industrial cultural heritage. A building for the museum was inaugurated in 1936, and the collections have remained there ever since. The museum became a foundation in 1947 and has received governmental support since 1964. Today, the museum produces exhibitions that focus on both industrial history and modern and future technologies. It also has a science centre called Teknorama.

The relationship between CID and the museum was initiated in 2000 through work on a production at the Swedish Museum of Natural History, where the current head of Teknorama worked at the time. When she moved back to the Museum of Science and Technology in early 2001, the collaboration with CID continued, mainly through activities within the EU/IST-funded project SHAPE (Situating Hybrid Assemblies in Public Environments). After SHAPE's public demonstration of an installation called *ToneTable* in January 2001, the museum became interested in hosting a similar exhibit in Teknorama, which initiated work that led to a new installation called the *Well of Inventions*. The *Well of Inventions* opened in May 2001, and at the time of writing (March 2005), it is still on display. *ToneTable* and the *Well of Inventions* are the focus of Papers C and E. In the summer of 2003, the Museum of Science and Technology signed a CID industrial partnership contract and a number of new activities were spawned, including an exhibit called the *Mighty Five* (described in Paper F), which opened in Teknorama in November 2004.

CID has produced and designed all the exhibits that have resulted from the collaboration with the museum. Although all of the productions have involved collaboration to a large extent, the main role of the museum has been to act as a host for the exhibits. Also, most of the funding for the activities (materials, technology, time spent, etc.) has been provided by different projects at CID. However, the CID exhibits have been treated by the museum staff as "proper" Teknorama exhibits, even though they are not part of the museum's general repertoire. The museum's educators have learned about the exhibits (and also present them on occasion), and they are overhauled regularly by the museum's maintenance staff.

CID and the Vasa Museum

Vasa is one of the world's most famous marine archaeological artefacts. In 1625, the Swedish king (Gustav II Adolf) commissioned a number of new warships, of which one was *Vasa*. The ship set out on her maiden voyage on 10 August 1628. However, because of a number of serious flaws in the design, the ship sank just a few minutes after she set sail. Since it was thought to be impossible to salvage the entire ship at the time (the depth was about 30 meters), she was left more or less as she was until 1956, when she was rediscovered by the shipwreck specialist Anders Franzén. On April 24, 1961, *Vasa* was salvaged and placed in a temporary building where she was conserved during the following 17 years. The current Vasa Museum was inaugurated in 1990.

During the fall of 2000, sulphate deposits were discovered on the surface of the ship. This led to the discovery that the wood contains a large amount of sulphur (assimilated from the water when the ship was resting on the sea bottom), which has gradually reacted with oxygen to form sulphuric acid. The acid and its deposits threaten to destroy the ship if nothing is done to terminate the process. Today, the reasons behind the problem are well understood, but a satisfactory solution does not yet exist (Sandström et al., 2003). Five different chemistry and conservation research teams have been engaged to study the problem. In addition, a small temporary exhibition has been produced to inform the general public about the condition of the ship. During the spring of 2003, ideas for a new large-scale exhibition were discussed among the museum's curators. As the new exhibition was to present the complex results of the research to the general public in some way, it was felt that the museum needed to know more about user-oriented design. Consequently, CID was contacted by the person who was head of exhibitions at the time. The National Maritime Museums organization (of which the Vasa

Museum is part) signed a CID industrial partnership contract in the summer of 2003.

Because of the large scope of the production, and because of frequently changing requirements, I suggested that CID focus on the part of the exhibition that seemed to be firmly established: the part where the general public was introduced to the sulphuric acid problem. This led to the research activities described in Paper B. The intention was to allow CID to develop a number of concepts, build a prototype exhibit, and evaluate it. If the exhibit was successful, CID would help to incorporate elements from the prototype into the actual exhibition. Unfortunately, the head of exhibitions left the National Maritime Museums organization during the spring of 2004, which caused the entire project to be postponed. Consequently, CID decided to focus on other activities, and there has been no further collaboration between CID and the Vasa Museum since.

CID and Swedish Travelling Exhibitions

Although Swedish Travelling Exhibitions is one of Sweden's most well-known exhibition producers, it is not a museum. Rather, it is a governmental authority that creates touring exhibitions. It started as a trial activity in 1965 and became an official government authority in 1985. One of the main goals of authority is to make culture (in the form of exhibitions) available to people who do not live in or close to the larger Swedish cities (where museums are abundant). Another important goal is to develop the exhibition medium itself: artistically, educationally, and technically. Many of the early productions consisted of touring collections of objects and works of art lent from different Swedish museums. Today, however, the content of most of the exhibitions is designed and developed by the authority itself. Swedish Travelling Exhibitions has also made use of a number of *mobile spaces*, that is, vehicles that have been converted into exhibition spaces (or have been built specifically for hosting exhibitions). Examples include boats, trains, buses, and trucks.

CID and Swedish Travelling Exhibitions established contact during the summer of 2003. The authority was in the early stages of producing a new exhibition about children's storytelling called *Once upon a time...*, which was to be the first to tour in the authority's new mobile space (a special-purpose truck that can be converted into 90 square meters of exhibition space). Furthermore, the intention was to work together with children to develop the content, and the exhibition would feature computer-based technology to support and encourage storytelling activities. As can be seen from the account in Paper A, such activities clearly matched CID's competence profile, so after a few meetings it was decided that CID would take part in the project, with two main goals: to assist with technology development and to establish a dialogue with the children. Swedish Travelling Exhibitions signed a CID industrial partnership contract, and I was invited to become a member of the project team. The first project meetings I attended took place during the fall of 2003.

Initially, the collaboration was fruitful. CID participated in meetings with different kinds of specialists, and also visited one of the schools that would provide access to the project's *reference group*, that is, a group of children (aged 11-13) who represented the target audience of the production. A few months into the project, a scriptwriter and a set designer were engaged to work with the content. However, as time went by it became increasingly difficult for the producer to find activities for CID to participate in. Clearly, CID had a competence profile that should fit the project but nevertheless, it was difficult for the producer to find a suitable role for the design centre. On August 23, 2004, CID was formally asked to leave the project. From CID's point of view, the reasons for why the collaboration was unsuccessful were puzzling. Consequently, I decided to attempt to analyse the process. The study, analysis, and results, which should be seen as a separate knowledge contribution to this thesis (in addition to the papers), are described in Chapter 3 below.

Research questions, perspectives, and scientific method

This thesis is concerned with the design of technology for museum exhibitions. More specifically, I have been particularly interested in the ways in which visitors can contribute to museum exhibition design and how technology can support learning-related activities within museum exhibitions. The research has been carried out from a *visitor-oriented perspective*, that is, the research focuses on visitors, visitors' activities within the museum, relationships between visitors, and relationships between visitors and the museum. Thus, the museum is considered to be a context for the work. More specifically, the work focuses on two main issues: *participatory design in museums* and *learning-oriented activities in museums*.

As outlined above, the design of exhibitions on cultural heritage is a well-established work practice that has been subject to numerous significant changes over the years. Today, the audience's encounter with the exhibition appears to be an increasingly important concern for many exhibition designers. Technology is often considered a means of providing visitors with new experiences and opportunities for learning. However, it appears that researchers have only recently begun to show an interest in how modern technology *is actually being used by visitors* (e.g., Falk & Dierking, 2000, pp. 190-191; Heath et al., 2002), and many museums appear to be struggling in their efforts to incorporate new technologies in their established exhibition design practices (vom Lehn & Heath, 2003). Thus, on the one hand, many museums are seeking more visitor-focused ways of carrying out design (with the help of, for example, different forms of evaluation or feedback). On the other hand, many museums seem to have little experience with designing technology in a user-oriented fashion. Thus, HCI, with its long tradition of involving users in design, was in a position to provide museums with *new ways for audiences to contribute to exhibitions with their knowledge, experience, opinions, and desires*. Consequently, my first research question was

- How can knowledge of participatory design within HCI be applied in the museum domain to include visitors in the design and evaluation of exhibitions?

The second set of issues with which my thesis is concerned is *how technology can be used to support learning-related activities in museums*. Education and learning is of primary concern to most museums, and many museums base their notion of learning on constructivist epistemologies. These epistemologies, in turn, suggest that certain types of activities in museums, such as interpretation, communication and collaboration, are more important than others for supporting learning. Thus, my second research question was

- How can technology be used in museum exhibitions to support and orchestrate different social activities related to learning?

The two research questions can be seen as two different, yet interrelated perspectives on museum exhibition design. From the first perspective, the visitor's desires, wishes, experiences, and knowledge become the focus of the design activities. From the second perspective, different social activities and relationships between visitors in museums become the focus of the design activities. These two perspectives can (and in my opinion, should) be seen as complementary. Together, they outline an approach to museum exhibition design where *visitors are of primary concern*, both concerning the content presented in exhibitions and concerning the way exhibitions orchestrate and support different forms of social interaction.

The two research questions are largely *exploratory* in nature, that is, the goal was to learn more about the possibilities (and outcomes) of combining design methodologies with roots in HCI with design methodologies from the museum domain. To generate such knowledge, I have chosen to work in an *operational as well as observational* manner. The research is – intentionally – organized to cause an effect (with subsequent studies of the outcome) in the sense that I have adapted HCI methodologies for the museum domain and tried to investigate the outcome of applying them there. However, I have tried to do so in a way that respects the design traditions and design practices of the museum. Thus, most of the activities have been carried out with the intention of interfering as little as possible with the museum's normal activities. As described in Chapter 3, the main exception is the collaboration with Swedish Travelling Exhibitions, where the intent was to integrate participatory design methods within an actual exhibition.

To answer the research questions, it was also necessary to generate other types of knowledge, such as descriptive, explanatory/diagnostic, and historical/reconstructive knowledge. However, it should be noted that the research is *not* concerned with generating normative knowledge (that is, the development of guidelines and rules), nor is it concerned with generating predictive knowledge. Rather, the contributions should be seen as a foundation from which hypotheses and discussions concerning visitor participation in museum exhibition design could be developed.

To me, the nature of the research questions in combination with the visitor perspective suggested a *qualitative approach to knowledge generation*. In other words, the research has been concerned with the nature of the relationships between the participants and organizations involved in the case studies, the way the activities were designed and managed (and with what outcomes), how the participants experienced the collaboration, and how the subsequent exhibitions were received and interpreted by visitors. Consequently, the analysis and data collection methodologies used are highly qualitative in nature. Examples of data collection methodologies that appear in the thesis include interviews, contextual inquiry, and ethnography-inspired behavioural observation. The main analysis methodology used is grounded theory (Strauss & Corbin, 1998).

As we shall see, the activities described in the papers do not make a clear distinction between the design of technology and the design of exhibitions. The reason is that in museums, *the technology and its corresponding user interfaces cannot be considered in isolation* – the way the technology is designed influences, shapes, and even orchestrates people's activities (see, e.g., Hindmarsh et al., 2002). Thus, designing technology for the museum is not simply a matter of designing an appropriate user interface. Rather, it is about how technology can be integrated into exhibits and exhibitions and about how technology can support and suggest different activities and behaviours.

Stakeholders

The work reported on in this thesis addresses several communities. One important group is *persons involved in museum exhibition design*: producers, project leaders, exhibition designers, educational staff, technicians, and so on. For such persons, the work should be considered a *smörgåsbord* of techniques and technologies with two main functions: 1) supporting and facilitating dialogue between production teams and visitors and 2) supporting and orchestrating learning-related activities in exhibits and exhibitions.

Another important stakeholder group is *persons involved in HCI* who are interested in how participatory design methodologies can be applied within new domains. Such readers may be particularly interested in the way I have modified (and built on) existing methodologies within HCI, how the new methodologies have been received within the new domain, and the designs resulting from their use. Furthermore, the techniques and technologies for supporting learning-oriented activities in museums may very well be useful in HCI as well.

However, the most important stakeholder group is *museum visitors*. The main goal of the work reported on in this thesis is to provide new ways for the general public to communicate their wishes, desires, experiences and knowledge to museum exhibition designers. In other words, *empowering "ordinary" people* in order to provide them with new opportunities for shaping and influencing museum exhibition design is the core idea behind this thesis. Thus, the spirit in which my work has been carried out is that of *increasing opportunities for democracy*, that is, providing new ways for the general public to have a *direct influence over how their own cultural heritage is exhibited and portrayed*.

Thesis disposition

Figure 1 illustrates how the thesis is organized and how the research questions cut across the different papers.

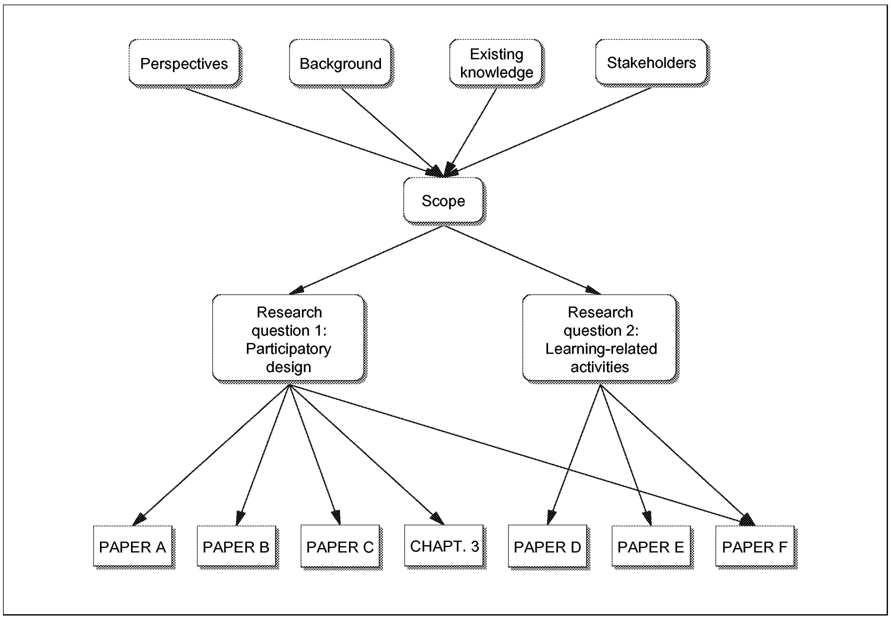

Figure 1. Thesis overview.

The rest of this thesis is organized as follows: Chapter 2 provides an overview of the papers that constitute the core of the thesis. As mentioned above, Chapter 3 contains an analysis of a breakdown of the collaboration between CID and Swedish Travelling Exhibitions. Chapter 4 discusses the knowledge contributions from the papers and Chapter 3 from a number of different perspectives. Chapter 5 draws a number of general conclusions from the work and suggests directions for future research.

2. Paper overview

This chapter contains an overview of the six papers on which this thesis is based.

Paper A: KidStory: A Technology Design Partnership with Children

Gustav Taxén, Allison Druin, Carina Fast, and Marita Kjellin
Behaviour & Information Technology, 20(2), March–April 2001, 119–125.

The roots of my work can be traced back to the EU-funded KidStory project (1998–2001), which was concerned with how children could work together with technology designers and educators to create storytelling tools. One outcome of the project's activities in Stockholm was a design methodology that made such collaboration easier. The methodology, which I designed together with other participants in the project, is summarized in Paper A. It is a variation of *cooperative inquiry* (Druin, 1999) and makes use of three different types of workshops:

- *Education workshops*, where the goal is to assist the children in constructing knowledge about design and technology.
- *Evaluation workshops*, where the goal is to assist the children in evaluating technology products and prototypes.
- *Brainstorming workshops*, where adults and children work together using low-tech prototyping to generate new technology ideas.

When KidStory began, the project differed from previous work in several important respects:

- The work was carried out in the school rather than in the laboratory.
- KidStory worked with younger children than previously (5–7 years old when the project started).
- KidStory worked with larger groups of children than previously (roughly 30 children participated throughout all three years of the project).

The KidStory work is, as far as I know, still unique in that it engaged such a large and heterogeneous group of young children in design for such a long time period. The design methodology worked very well and led to a number of interesting prototypes, some of which are described in Paper A. Although they were not thought of as such at the time they were developed, many of these prototypes can be seen as interactive exhibits or installations. Examples include a "story owl" that would tell you stories from around the world, a "magic sofa" that would transport its users to exciting places, and a "technology fair" where some of the prototypes were integrated and exhibited to the children's parents and relatives. Indeed, one of the more successful of the prototypes, a drawing application called *KidPad* (which was developed by Juan-Pablo Hourcade, Benjamin Bederson, me, and Allison Druin) has been featured in several exhibitions at the Museum of Science and Technology. This, in conjunction with the fact that the design methodology worked very well with such young participants, made the KidStory approach a suitable candidate for adaptation for the museum domain.

Paper B: Introducing Participatory Design in Museums

Gustav Taxén
In *Proceedings of the 8th Biennal Participatory Design Conference (PDC 2004)*, 27–31 July 2004, Toronto, Canada, 204–213.

The work described in Paper B addresses the conceptual phase of museum exhibition production. In the summer of 2003, CID was contacted by the director of exhibitions at the Vasa Museum in Stockholm, who was in the early stages of organizing a new production. Since it was very likely that the new exhibition would feature both advanced computer-based technology and provide visitors with complex information, she wanted to draw upon CID's usability expertise. At the time, it was known that the exhibition would contain a section with background information and a section with information that would be modified and developed over time. Because the background section seemed easiest to begin with, it was decided that the collaboration between CID and the Vasa Museum should focus on that.

Paper B describes how I designed, organized, and hosted a series of workshops where a number of the museum's educators and curators worked together with representatives of one of the target groups of the exhibition – high school students – to create concepts for providing visitors with background information. The workshops were based upon the KidStory methodology (although, as it turned out, no educational sessions were necessary). The students first evaluated the current exhibitions at the Vasa Museum, which resulted in a set of "design sensitivities" that guided the rest of the work. Two sessions followed in which the students worked together with members of the museum's staff to develop and refine concepts for the new exhibition. The final session was devoted to feedback: I provided the students with an overview of how their concepts related to current trends within museum research, and the students provided me with their opinions on the work methodology itself. The outcome of the design activities was three detailed exhibition concepts with a number of interesting technological and paedagogical features. As described in the paper, these features were also relevant in the sense that they addressed current issues within museum technology research.

Paper C: The Well of Inventions - Learning, Interaction, and Participatory Design in Museum Installations

Gustav Taxén, Sten-Olof Hellström, Helena Tobiasson, Mariana Back, and John Bowers
In *Proceedings of the Seventh International Cultural Heritage Informatics Meeting (ICHIM 2003)*, 8–12 September 2003, Paris. CD-ROM Proceedings.

A large amount of my work has been carried out as part of the EU-funded SHAPE project (2001-2004). One of the main goals of SHAPE was to investigate how assemblies of technology could provide new forms of public experiences, with a particular focus on public experiences in museums. As described in Paper C, *ToneTable*, one of the first demonstrators of the project (designed and developed by John Bowers, Sten-Olof Hellström, and me in February 2001) was extended and redesigned by me, Sten-Olof Hellström, and Helena Tobiasson to become the *Well of Inventions*, a small exhibition that opened at the Museum of Science and Technology in Stockholm on 22 May 2001.

Similar to many other museum exhibitions, the *Well of Inventions* was evaluated through behavioural observation and interviews with visitors and museum staff (carried out by me, Sten-Olof Hellström, and Helena Tobiasson). However, the exhibition was also evaluated in a series of workshops, which I designed, organized and hosted. The main goal of these workshops was to provide an opportunity for visitors to provide direct feedback, with a particular focus on generating ideas for improving the exhibition. In terms of participatory design, the *Well of Inventions* was a prototype, and the workshops were designed to provide ideas for refinement.

When I compared the data that resulted from the workshops with the data generated by the behavioural observation and interviews, it became clear that, to a very large extent, the issues raised in workshops were similar to those raised by the other forms of evaluation. Thus, the workshops provided relevant evaluation data. But in addition, the workshops also provided numerous design ideas for improving the exhibition.

Paper C also describes how constructivist models of learning motivated the design of the *Well of Inventions*. As described in Paper D, one of the core notions within constructivism is that learning is, to a large extent, supported and aided by discussion and dialogue between people. Thus, one of the main goals of the *Well of Inventions* was to augment the basic interaction principles present in *ToneTable* with new content to encourage such discussion and dialogue, in particular concerning topics related to basic principles of mechanics (to which a large portion of the Museum of Science and Technology is devoted). A more detailed overview of the design of the *Well of Inventions* and the evaluation workshops can be found in my licentiate thesis (Taxén, 2003).

Paper D: Teaching Computer Graphics Constructively

Gustav Taxén
Computers & Graphics, Vol. 28, No. 3, June 2004, 393–399.

A central issue in this thesis is that of learning, and Paper D provides an account of the epistemology and philosophy of learning that has been most influential in my work, that of *constructivism*. The central notion of constructivism is that we construct our own individual understanding of what we experience and that we are constantly renegotiating this understanding through communication with others. Thus, for constructivists *there can be no transfer of knowledge*. In other words, knowledge cannot be directly "transmitted" from one person to another. Rather, constructivists tend to see the development of a shared understanding as a *social negotiation* that is mediated through, say, spoken language or written text. Paper D reviews two influential constructivist epistemologies and outlines a number of corresponding paedagogical and didactical approaches. The paper also describes how I attempted to introduce such a didactical approach in university education.

It is important to note that I am in no position to argue that constructivist epistemologies represent the truth of how learning takes place; neither in museums nor elsewhere. Just like many museums do today, I tend rather to view constructivism as an interesting philosophy for guiding the design of exhibitions. In other words, the learning-related contributions of this thesis are not primarily concerned with the outcome of the learning processes that occur in museums. Rather, the contributions should be seen as examples of how constructivist philosophies and epistemologies can *provide novel approaches towards the design of exhibition technology*.

Paper E: Designing Mixed Media Artefacts for Public Settings

Gustav Taxén, John Bowers, Sten-Olof Hellström, and Helena Tobiasson
In Darses, F., Dieng, R., Simone, C., and Zacklad, M. (Eds.) *Cooperative Systems Design. Scenario-Based Design of Collaborative Systems.* Amsterdam: IOS Press, 2004, 195–210.

Paper E provides additional details of the relationship between *ToneTable* and the *Well of Inventions*. As described in Paper C, one goal of the *Well of Inventions* was to encourage discussions and dialogue between museum visitors. Another important goal was to retain many of the desirable features in *ToneTable*. The most important of these was *ToneTable*'s ability to encourage collaboration and coordination between users. Paper E describes how a set of *design sensitivities* (developed by John Bowers, Sten-Olof Hellström and me) inspired the design of *ToneTable*, how these sensitivities were evaluated, and how they were incorporated in the *Well of Inventions*.

Paper F: The Extended Museum Visit: Documenting and Exhibiting Post-Visit Learning Experiences

Gustav Taxén and Emmanuel Frécon
In J. Trant and D. Bearman (eds.). *Museums and the Web 2005: Proceedings*, Toronto: Archives & Museum Informatics. CD-ROM Proceedings.

Paper F describes an attempt at allowing visitors to contribute with content for an exhibit in its functional phase, that is, when it is on display. The exhibit, which I conceptualized, was hosted by the Museum of Science and Technology and was designed and implemented in collaboration with Emmanuel Frécon and Anders Wallberg at the Swedish Institute of Computer Science. The intention was to support a group of exhibits in the museum's science centre called the *Mighty Five*, which illustrate five mechanical principles: the screw, the plane slope, the lever, the wheel, and the wedge. The main inspiration for the new exhibit was constructivist-oriented research on post-visit experiences (e.g., Falk & Dierking, 2000), which suggests that the learning processes that take place in the museum do not end when visitors leave. Rather, it seems that many people draw fundamental conclusions that are related to their visit *outside* the museum, after the visit, when they encounter a situation that allows them to "make a connection". Documenting and exhibiting such situations was the main goal of the new exhibit, which was designed as a virtual logbook where visitors could record their museum-related experiences through cell phone SMS and MMS messaging or through e-mail.

As it turned out, it was very hard to encourage visitors to contribute from outside the museum. The evaluation of the exhibit suggested that this was partly due to problems with the design and location of the exhibit itself. It also appears that for many people, the museum visit ends when they leave the building, that is, it has no conscious post-visit phase where the experiences of the visit are developed and elaborated upon. Thus, even if a situation is recognized as a museum-related learning experience, it may be difficult to remember the *Mighty Five* exhibits. More importantly, however, there is no immediate "reward" for contributing from outside the museum – it is impossible to see how the contribution appears in the exhibit unless one returns to the museum later.

Nevertheless, I collaborated with the museum to organize a set of paedagogical activities in the museum that involved the logbook. For example, we developed and organized a "treasure hunt" where children would search the museum for machinery that implemented the mechanical principles depicted in the *Mighty Five* exhibits. The children would then use a digital camera to send pictures back to the logbook. This was a successful activity, and the museum has subsequently repeated it with a number of groups of children of different ages.

Summary of personal contributions

Paper	Contributions
A	Wrote paper. Co-authors contributed with paragraphs, comments, suggestions, and took part in the work described in the paper. Methodology development: preparatory work, methodology design, session design, session facilitation, data collection, collaboration with children. Programming: wrote code for *KidPad* and other prototypes.
B	Wrote paper. Methodology development: preparatory work, methodology design, session design, session facilitation, data collection, analysis of session outcomes.
C	Wrote paper. Co-authors contributed with comments, suggestions, and took part in the work described in the paper. *ToneTable*: co-designer, designed and implemented the graphics and input device support, technical integration, session facilitation, data collection. *Well of Inventions*: project leader, concept designer, designed and implemented the graphics and input device support, technical integration. Evaluation methodology development: preparatory work, led the summative evaluation work, summative data collection, designed and facilitated workshop data collection, data analysis, triangulation.
D	Wrote paper. Methodology development: preparatory work, methodology design, session design, session facilitation, data collection, analysis of session outcomes.
E	Wrote paper with John Bowers. Edited the paper. Other co-authors contributed with comments, suggestions, and took part in the work described in the paper. Co-designer of the "design principles", adapted the principles for the *Well of Inventions*, data collection (*Well of Inventions*), data analysis (*Well of Inventions*).
F	Wrote paper. Co-author contributed with paragraphs, comments, suggestions, and took part in the work described in the paper. Project leader, concept designer, designed and implemented the graphics and the client software, data collection, data analysis, initiated paedagogical activities, co-facilitated paedagogical activities.

3. When design traditions clash

Gustav Taxén
March 2005

As described in the Introduction, Swedish Travelling Exhibitions and CID initiated collaboration on a new exhibition called *Once upon a time...* during the fall of 2003. Although the collaboration was fruitful initially, it became increasingly difficult for the producer to find activities for CID to participate in as the project proceeded, and in the fall of 2004 the collaboration broke down. From CID's perspective, the reasons behind the breakdown were unclear, so I decided to attempt to analyse the situation. This chapter contains a description of the analysis and the results and should be seen as a separate knowledge contribution to this thesis (in addition to the papers).

The analysis was carried out using the Grounded Theory methodology (see, e.g., Strauss & Corbin, 1998), and it is based upon two open interviews (conducted on 17 September 2004, and 18 January 2005) with the producer. The basic set of concepts and relations in the analysis were abstracted from the first interview. The second interview provided further detail, a few corrections, and additional data for a few unclear concepts and relations. After the analysis was complete, it was sent back to the producer for verification. Appendix A contains the coding of the concepts and relations.

Note that the analysis does not constitute a theory in the sense of Strauss and Corbin. The goal here was not to build theory but rather to understand the relationships between the actors involved and the complex chain of events that led to the breakdown.

Project timeline

The production of *Once upon a time...* is summarized in the *project timeline* diagram (Figure 2, overleaf). This diagram features the most significant project contributors and illustrates in which phase of the production they are most important. Note that most projects at Swedish Travelling Exhibitions (STE) are different from one another, and it is not at all certain that all projects are carried out in the same way as *Once upon a time...* Most productions, however, seem to go through the same general phases as productions at other exhibition producers (that is, conception, development, a functional phase, and assessment).

The production process (which is laid out horizontally in the centre of the diagram, from left to right) begins with a project *proposal*. All proposals are *screened* by the *U.T.E. group*. The abbreviation (in Swedish) refers to the three main members of the group, which are the *director of exhibitions*, the *head of technology*, and the *head of Expoteket* (which is STE's library and archive of previous productions). Other participants in the group are the *deputy director of exhibitions*, and the *exhibition assistant*. STE's *commission* from the *Ministry of Education, Research, and Culture* is freely interpreted by STE, which results in a number of *priorities*. These priorities are one of the tools that the U.T.E. group uses to determine whether or not a project proposal should be accepted. Projects that pass the screening process are also subjected to an additional *selection*, which is carried out by the director of exhibitions. Here, important factors include the artistic potential of the proposal and whether it fits STE's current *repertoire*. If the proposal is accepted, it becomes the foundation for a *feasibility study*, and a *person responsible for the study* is selected. This person may be a producer at STE or someone else. In *Once upon a time...*, the person responsible for the feasibility study was the person who then became producer of the exhibition.

The purpose of the feasibility study is to turn the project proposal into a description of an exhibition project. This description includes a *goal description*, a *budget*, and an outline of a *tour plan*. The goals of the exhibition are formulated by the person responsible for the feasibility study, and they are shaped by a number of factors, including *planned external activities*, *meetings with specialists* and *contributions from external partners*. When the feasibility study is complete, it is sent back to the director of exhibitions who *decides* whether or not the project should be carried out.

This leads to a *design process* where the *content* of the exhibition is created. The *project leader* and the *producer* are important during this phase. The project leader is responsible for keeping the budget and time plan of the project, while the producer has the *artistic responsibility* (more on this later). In *Once upon a time...*, the same person was both producer and project leader. The *project team*, that is, the team responsible for designing and implementing the exhibition and its tour, also included a *technician*, an *exhibition coordinator*, and three external partners. They were the *scriptwriter*, who was responsible for the textual/linguistic content of the exhibition, the *set designer*, who was responsible for the physical shape of the content, and myself.

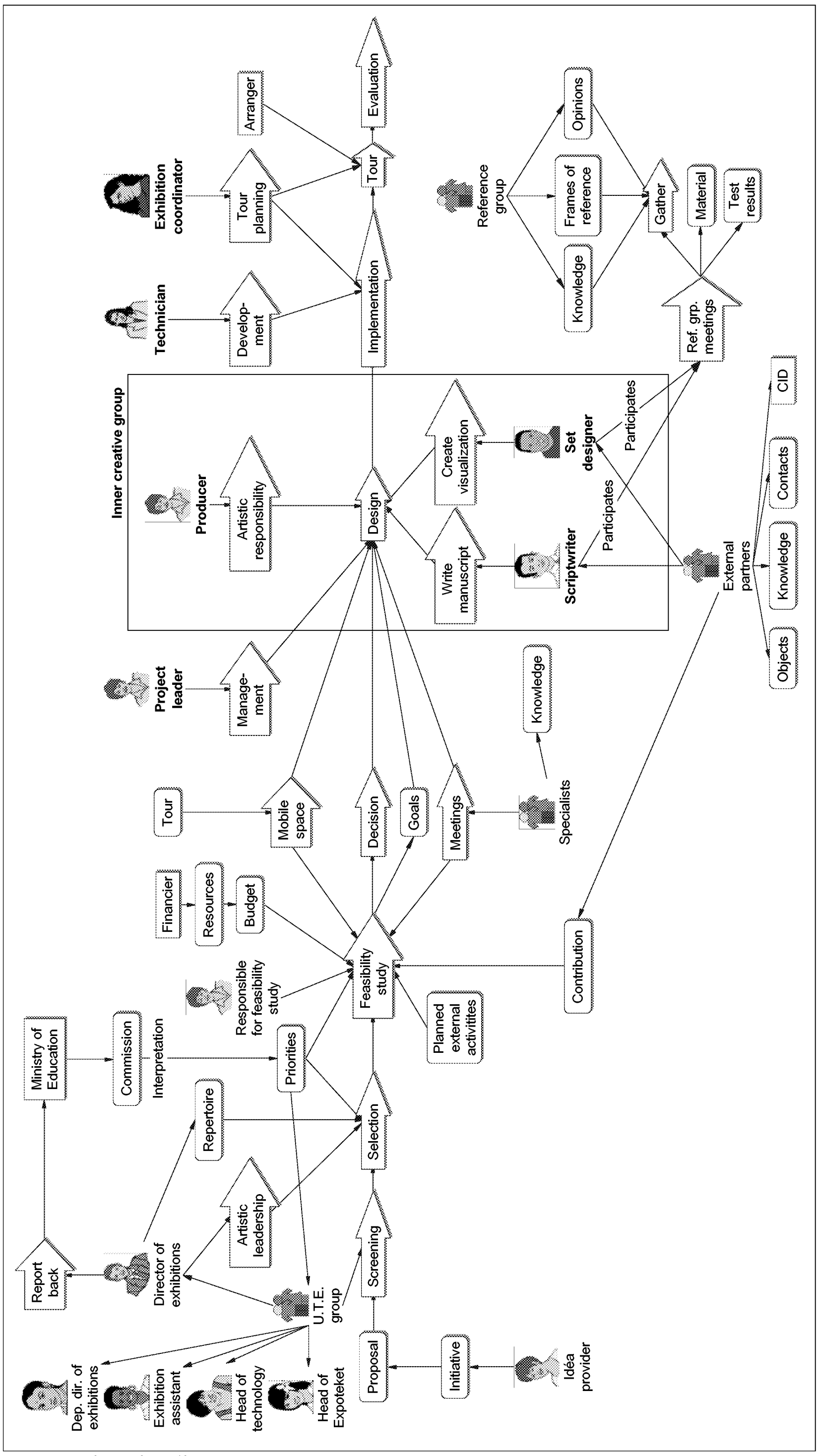

Figure 2. Project timeline.

When the content of the exhibition has been fully developed, an *implementation phase* follows. The goal of this phase is to use technology to turn the description of the content into a (physical) exhibition and prepare it for its *tour*. The exhibition is received by *arrangers*, for example, museums, libraries, or art galleries. Some arrangers are invited to arranger seminars (hosted by STE) where they can give feedback on existing exhibitions and provide suggestions for future productions.

Typically, each production is also *evaluated*, both concerning the way the exhibition is received by its audience and concerning the design process.

Design process

The *design process diagram* (Figure 3) illustrates how I have interpreted the design phase of *Once upon a time...*, that is, how the different actors and the most important concepts relate to one another. Again, it should be noted that all of STE's productions are different and that it is not at all certain that all design processes work in the same way as in *Once upon a time...* Nor is it certain that the design process continued in the way described here after CID was asked to leave the project.

There are five types of actors in the diagram: *producer*, *external partners*, the *inner creative group*, the *reference group*, and the *recipients*. Each type of actor is represented by a grey box which surrounds the concepts that "belong" to the actor. Two central/fundamental concepts are marked in bold: *introduction process* and *project phase*. As described below, these concepts are likely to be the key to the reason why the producer decided to interrupt the collaboration with CID.

STE's *commission* entails a number of goals and directives, including the requirement of reporting back to the Ministry of Education, Research, and Culture. STE interprets these goals relatively freely, which leads to a number of priorities, which in turn shapes the *feasibility study*, which in turn provides the overall *goals* for the exhibition. One of STE's priorities is children and adolescents, which is one of the reasons why *Once upon a time...* was given the go-ahead. The goals of the feasibility study are those goals against which the *content* of the exhibition is compared and interpreted.

Each potential external project partner has a set of *work skills*, and a prerequisite for being able to participate in the project is that these work skills "match" whatever the producer feels is required at the time of introduction. Work skills include, among other things, *experience*, *openness* (that is, that one allows oneself to be influenced by others), *values and opinions*, *knowledge*, and *interests*. When the existence of a potential project partner becomes known to the producer, an *introduction process* may be initiated. During this process, the producer acquires *knowledge* (which may or may not be correct) about the partner's work skills. This knowledge determines whether the partner is *suitable* for the project.

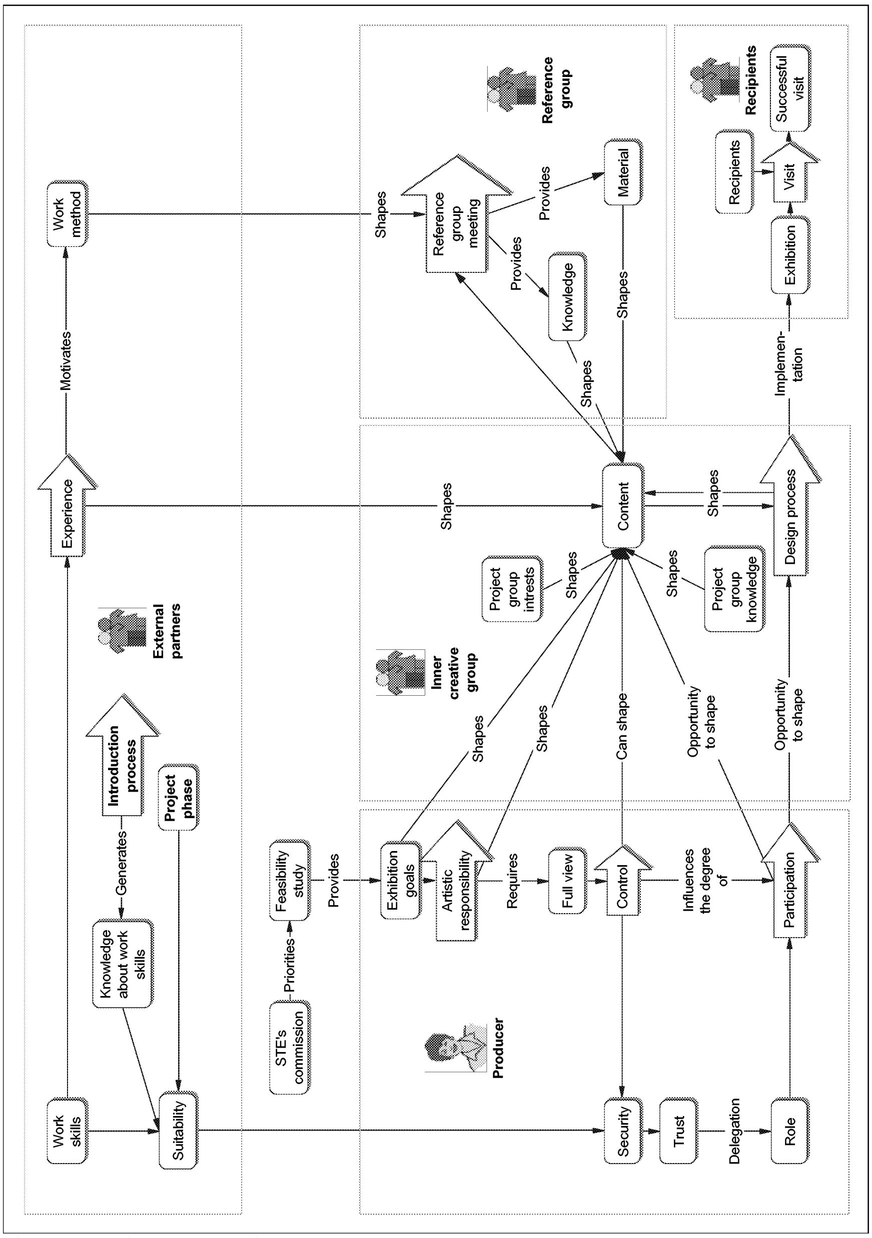

Figure 3 Design process diagram.

In *Once upon a time...*, the inner creative group was responsible for the *design process* that produces the content of the exhibition. A number of factors shape the content. First, the high-level goals from the feasibility study are continuously interpreted by the members of the project team according to their *knowledge* and *interests*. Second, the producer takes part in the discussions of the inner creative group and, if necessary, exercises control over the content if it fails to meet the goals of the feasibility study. Third, the content is shaped by the *experience* of each external partner. For example, at an early stage during the production of *Once upon a time...*, it was decided that the content should be based upon features from the scriptwriter's previously published books and CD-ROMs for children. Experience appears to be a fundamental part of the partners' work skills; if a partner has experience that is suitable for the project, that partner is also assumed to be able to develop a strategy for accomplishing the goals of the project.

Thus, experience motivates one or several *work methods*, which shape the design process and the meetings with the reference group. It was felt to be necessary for the inner creative group to have some sort of idea for the content of the exhibition before they could meet with the reference group. Such ideas were influenced by the goals in the feasibility study, but above all, they were defined by the work of the inner creative group. The ideas could be unclear and vague, but some form of foundation for the discussion with the children was definitely considered necessary.

The content of the exhibition is shaped by the design process, but the design process is itself shaped by the content. For example, in *Once upon a time...*, the scriptwriter created a "map" of potential themes for the linguistic content of the exhibition, and the inner creative group then selected a subset of these themes for refinement (which is an activity that is different from selection). Thus, the design process is not static, but changes and evolves together with the content.

During its tour, the exhibition is *visited* by *recipients*. If the exhibition is designed "correctly", each visit has the potential to become *successful*. What constitutes a successful visit is partly described in the goals for the exhibition, but it is also assumed that the external partners that are invited to participate in the project have knowledge that allows them to design for successful visits. In other words, it is the work skills of the participants that are the foundation for a successful exhibition design.

Interpretation

In *Once upon a time...*, the inner creative group was the catalyst that would help define the linguistic and physical content of the project. Clearly, the interests and knowledge of the entire project team were important and taken into account, but *only the inner creative group had a direct influence over the content*. The work methods chosen by the inner creative group shaped the meetings with the reference group and defined the purpose of each meeting.

There was no detailed plan for the content when the director of exhibitions at STE decided to accept the proposal for *Once upon a time...* The goals in the feasibility study were (deliberately) rather abstract and relatively vague with respect to content. One reason for this was that, during the feasibility study before CID joined the project, the producer had decided to engage a scriptwriter and a set designer to create the content. These two persons would be inspired by the children and learn more about them during the reference group meetings. Exactly *how* this was to be accomplished was not described in the feasibility study. Rather, the scriptwriter and set designer would be free to formulate an appropriate work method themselves, although the aim was to let the reference group meetings and content develop together in interplay. Still, it was vital that the *experiences of the scriptwriter and the set designer became the foundation of the content*. The artistic ability and creativity of these persons – that is, their work skills – guaranteed quality. The role of the reference group was mainly to provide inspiration and knowledge and, to some extent, to act as a focus group for testing ideas. This approach towards design was well-known to the producer and was felt to be natural, and she knew that it had been used successfully in other contexts.

CID, on the other hand, advocated an approach where the content would *be shaped directly by the opinions, points of view, and wishes of the reference group*. CID represented a perspective where the *recipients* of the exhibition are seen as the most important persons to consult if one wants to create inspiring and motivating content. Thus, the main purpose of the reference group meetings would be not to provide inspiration and knowledge but rather to allow the children to *participate directly in the creation of the content*. CID had used such an approach successfully in previous projects (for example, in KidStory), and were very much interested in using the approach again. Thus, CID strongly believed that the *children's* experiences (rather than those of the scriptwriter and set designer) should become the basis for the content of the exhibition. The work methods that CID had used in previous projects would guarantee quality. From CID's point of view, the scriptwriter and set designer should have met the reference group *before* they began to develop the content. This did not happen, however. Rather, the scriptwriter started the design activities by creating a "map" of themes and approaches for the exhibition. These themes and approaches were largely put together from the content of his previously published books and CD-ROMs for children. The "map" became the foundation from which the content of the exhibition was developed and became the focus of the reference group meetings.

These two perspectives on design are obviously quite difficult to unite. Consequently, it was hard for CID to arouse enthusiasm for their proposals. During the feasibility study, the project had been designed with a specific focus on the scriptwriter and set designer. Therefore, it became impossible to allow the reference group to provide the foundational themes of the content during the design phase since such an activity would conflict with the assignments and roles already given to the scriptwriter and set designer. CID also failed to provide STE with suitable information about their user-oriented perspective and the work methods they had used in previous projects. The way CID reasoned with respect to design was unknown to the producer, which made communication even more difficult. Consequently, *the process that introduced CID to STE failed*. If CID had been introduced earlier during the feasibility study (before the overall approach had been decided upon) it might have been possible to integrate CID's user-orientation focus with the producer's focus on the work skills of the scriptwriter and set designer.

In summary, the *introduction process* and the *project phase* are central concepts in the analysis. The conclusion is that for *Once upon a time...*, the *project participants were not introduced in an appropriate way* and the actual introduction *took place at an inappropriate time*.

These results are discussed further in the next chapter.

4. Discussion

This chapter discusses the knowledge contributions provided in the six papers and in Chapter 3 above. It is important to note that this summary should not be seen as a separate knowledge contribution. Rather, it should be seen as a restructuring of the contributions provided in the papers and Chapter 3 with the goal of *making it clear how the contributions match the research questions*. Thus, the chapter focuses on a number of perspectives that are related to each of the research questions and describes how these cut across the different papers. Figure 4 illustrates how the chapter is organized.

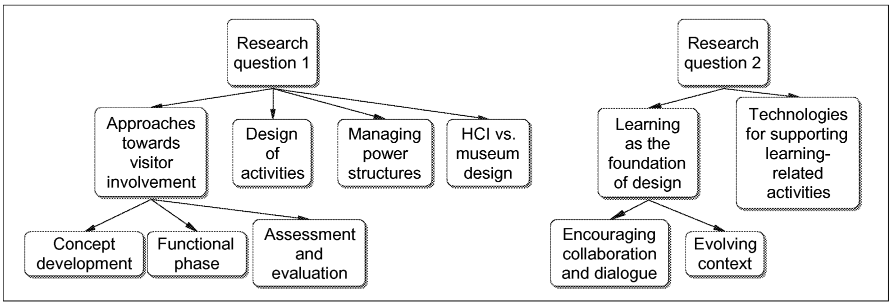

Figure 4. Organization of the discussion chapter.

Research question 1: Participatory design and evaluation methodologies in museum exhibition design

My first research question is concerned with how visitors can be involved in the design and evaluation of museum exhibitions. For the purposes of this discussion, I have chosen to explore the knowledge contributions related to participatory design work in museums from four main perspectives:

1) Approaches towards involving visitors in the conceptual, functional and evaluation phases of museum exhibition design.
2) The practicalities of hosting design and evaluation sessions with visitors within the museum context.
3) The challenges of managing power structures between visitors and "professionals" in museum exhibition design.
4) The challenges of using participatory design within established exhibition design practices.

The following sections describe these perspectives in further detail.

Perspective 1: Approaches towards involving visitors in museum exhibition design

As described in Chapter 2, the background for my work on visitor participation in museum design is the KidStory design methodology (Paper A). The KidStory design methodology made use of *educational sessions*, *evaluation sessions*, and *brainstorming sessions*, each with a special emphasis on *generating new design ideas*. Paper A provides the underlying motivation for each type of session and illustrates how the different motivations have been carried out in practice. The KidStory project had a number of positive outcomes, including:

- A design methodology that was able to involve young children in iterative design and evaluation of technology.
- A large number of novel design ideas, both with respect to existing products and prototypes (suggestions for refinement) and with respect to new concepts.

It was mainly these capabilities that I wanted to retain when I began experimenting with involving visitors in exhibition design.

As described in the Introduction, many museums are seeking more visitor-focused ways of carrying out design. Thus, an important goal was to determine whether participatory design methodologies could facilitate a dialogue between visitors and museum staff during the exhibition production process. Most museum exhibition design projects consist of four main phases: *concept development*, *exhibition development*, a *functional phase*, and an *assessment phase*. During the exhibition development phase (when the exhibition is constructed), it is not uncommon to invite visitor representatives to provide feedback on mock-ups or early versions of exhibits, so called *formative evaluation* (see, e.g., Caulton, 1996, pp. 39–43). Because formative evaluation appears to be a rather well-developed practice, I chose to focus on the other three phases of exhibition design, for which there appears to be substantially fewer methodologies available.

Concept development

Paper B describes how visitors can contribute during the conceptual phase of museum exhibition design. Because the visitors I chose to work with already knew the background of the exhibition (through educational activities at the museum), there was no need for initial educational sessions. Thus, the session activities consisted of evaluating existing exhibitions and of brainstorming to develop new exhibition concepts.

The evaluation session was different from the sessions used in KidStory in that it did not involve contextual inquiry. I avoided using contextual inquiry because I thought it might be awkward to use in the crowded (and often noisy) environment of museum exhibitions and because I wanted to experiment with methodologies that allowed a more “quick-and-dirty” collection of opinions. Furthermore, I wanted to see whether an exhibition evaluation activity could provide a starting point for the concept discussions (as was done in KidStory). Because the visitors were to be the primary providers of ideas for the new concepts, I felt that it was important that the visitors evaluate the exhibitions themselves (rather than, say, providing them with a pre-written list of “guidelines”). Another reason was to encourage them to become familiar with the details of the museum’s exhibitions.

Although Allison Druin has successfully taught users how to use different variations of contextual inquiry (see, e.g., Druin, 1999), I felt that a less formal methodology might be more useful in the museum context. As part of an experience exchange effort within KidStory, I worked three months at the Human-Computer Interaction Lab at the University of Maryland. There, I encountered a variation of the *future workshop* (Kensing and Halskov Madsen, 1991, Bødker et al., 1993) that was designed to allow children to quickly evaluate existing technologies. It proceeded as follows: First, the children were allowed to interact with the technology. Then, they were asked to write down three good aspects and three bad aspects of the technology on Post-It notes and bring them to the workshop facilitator. The facilitator would then group notes with similar content on a whiteboard. When all notes had been put on the whiteboard, the facilitator would summarize the content of each group by adding an appropriate heading. These headings were then used as the basis for small-group discussions on possible modifications of the technology. The methodology appeared to work very well and seemed to be suitable for a museum context. However, I felt that it was important that it was the visitors who chose how to group and summarize the Post-It notes rather than the session facilitator, and modified the methodology accordingly. The result is described in detail in Paper C (see also Taxén, 2003).

The brainstorming sessions were carried out as in KidStory to a large extent, and were primarily concerned with low-tech prototyping. Just as in KidStory, they also involved selection by researchers, but rather than isolating a number of ideas for implementation, the choice aimed at highlighting interesting features that were felt to have potential for elaboration. Thus, the selection process was more about suggesting a focus for the following brainstorming session than choosing one (or a few) ideas for further development. Another difference was the addition of an activity where the participants storyboarded and videotaped different usage scenarios. The main reason for including these was to encourage the session participants to shift their focus from appearance and content towards usage and accessibility (c.f., Mackay et al., 2000).

As reported in Paper B, the museum brainstorming sessions had a number of outcomes that were similar to the outcomes of the KidStory methodology, including:

- The museum design sessions were able to involve "non-professionals" in the design of exhibition technology.
- The sessions generated numerous design ideas.
- These design ideas were also relevant in the sense that they addressed issues that are currently being discussed within contemporary museum technology research.

Functional phase

It is not uncommon for visitors to be invited to contribute with content for museum exhibitions, either through material collected by the design team during the conceptual and development phases of exhibition design (an example is provided in Chapter 3) or while the exhibition is on display (for example, the voting exhibits in the *In Future* gallery of the London Science Museum's *Wellcome Wing*).

The work described in Paper F provides an additional approach towards using technology to provide opportunities for visitors to shape the content of exhibitions. The paper describes how contemporary communications technology can be used to allow visitors to contribute to an exhibition from an *unspecified location* (both inside and outside the museum). The exhibit had two main goals: 1) to see whether it was possible to document and exhibit learning processes that take place outside the museum and 2) to provide a "real-world" context for an existing set of exhibits (see below for a more detailed discussion of these goals).

It should be noted that it is not the concept of allowing visitors to contribute to the content of exhibitions that is novel here. Rather, I am of the opinion that the novelty lies in the *primary function* of the visitor contributions, that is, the very essence of the exhibit is *the visitors' own interpretation* of different museum artefacts they have encountered during their visit (and elsewhere), and this collective interpretation is allowed to change and evolve while the exhibition is on display. In a sense, the visitors are *creating the exhibit* as they interact with it (c.f., Samis, 2001).

I have been involved in another exhibition, *Re-Tracing the Past* at the Hunt Museum in Limerick, Ireland, that takes this idea even further (Fraser et al., 2004). The focus of the exhibition was four "mystery objects"; that is, four objects that the museum had been unable to classify, and visitors were encouraged to propose their own interpretation of one or more of these objects through interaction with a number of different exhibits. These exhibits provided opportunities for visitors to access information related to the origin of the objects, the circumstances of their discovery, and their material qualities. One of the most important assemblies of technology in the exhibition was a combination of a recording station, an animated visualization, and an old radio. This assembly allowed visitors to record their interpretation of the four objects, and to listen to recordings other visitors had made. Thus, the visitors were not only shaping the exhibition as it was on display, they also *acted as curators*.

Assessment and evaluation

Many museums evaluate their exhibitions, often through methods such as questionnaires, behavioural observation, and interviews (Binks and Uzzell, 1994). I was interested in whether visitors and museum staff could become involved in a less formal dialogue on evaluation, and in particular whether visitors could contribute with suggestions for improvement as part of an iterative design process. The experiment is described in Paper C (see also Taxén, 2003). In an attempt to establish relevance, I also compared the outcome of the workshop-based evaluation with "traditional" museum evaluation. From a research perspective, the comparison can be seen as a form of triangulation, since it juxtaposed and interrelated data acquired from different sources and through different activities. The data sources were:

- The workshop Post-It notes (and their organization into groups) and notes taken during the large-group discussions.
- Notes from behavioural observation of visitors interacting with the exhibit in question.
- Structured short interviews with museum visitors.
- Semi-structured deep interviews with members of the museum staff.

The comparison loosely followed the initial steps of the grounded theory method (Strauss & Corbin, 1998). A coding of the Post-It notes and discussion notes provided a number of initial concepts, which were compared to a similar coding of the observation notes and interviews. As described in Paper C, the resulting concepts can be grouped under five themes (education, audio-visual aspects, engagement, collaboration, and physical design). The main difference between the data from the workshops and the data from the summative evaluation is that the workshop data also contained a large number of design suggestions. Thus,

- The evaluation workshops were able to involve "ordinary people" in the evaluation of museum exhibitions in the sense that the activities facilitated a dialogue between visitors and exhibition designers.
- Even though the workshops required a relatively small amount of resources, they generated a large amount of qualitative data, much of which were in the form of design suggestions.
- The workshop data were relevant in the sense that it emphasized largely the same issues as the summative evaluation.

Perspective 2: Design of sessions

Another perspective on involving visitors in museum exhibition design is the practicalities of the design activities: how can they be managed and carried out? In the reporting of my research, I have chosen to follow Allison Druin, Michael Muller, and others in that I tend to describe the practicalities of the activities in detail. The reason is that it appears that the practical circumstances of a session – for example, how participants are prepared (if at all), how activities are ordered and carried out, how much time is spent on each activity, the kinds of work materials available – can have a substantial effect on the outcome (see Alborzi et al., 2000; Druin, 1999; Muller, 1993; or Muller, 2001 for examples).

However, it is important to remember that such descriptions of context and its effects may not necessarily be generalizable to other domains. For example, I believe that it would be problematic to claim that a given set of activities in combination with a certain set of work materials will always have similar design outcomes, regardless of who the participants are. Rather, I believe that it is the *combination* of the participants' background, knowledge, and interests and the way in which the activities are orchestrated that shape the results. Consequently, I have tried to be sensitive to the *interplay between the circumstances of the activities and the participants* in my accounts of the design and evaluation sessions (see Dourish, 2003, for a detailed discussion of different interpretations of context and the interplay between context and individuality).

As described in Paper A, the KidStory project devoted a large amount of time to design sessions, and the nature of these sessions evolved constantly as children and adults became more used to each other and to the project. Almost all the sessions during the first six months of the project consisted of educational exercises (of which the "inventing a sandwich" activity described in Paper A was one). The project gradually introduced sessions with evaluation activities (mainly testing and discussions of different kinds of software), and the first brainstorming activities appeared at the beginning of the second year.

As described in Sundblad et al., 2000, each KidStory session was unique. The reasons included:

- Children and adults were learning how to become design partners as they went along: some sessions were more successful than others, which prompted the adults to explore different approaches and activities.
- As the children became more familiar with the project and its goals (and the technology prototypes became more flexible and mature), it was possible to introduce more design-oriented activities into the sessions.

- As the project proceeded, the adults got to know the children, their habits, their preferences, and their interests, which made it easier to plan the session activities.
- However, working with the children always seemed to lead to unexpected situations and problems, which required the adults to improvise to a large extent.

Most sessions, however, where quite informal, and every session (with very few exceptions) had an introductory activity (for example, sit in a ring on the floor and discuss the goals of the session) and a final activity (for example, reconvene on the floor and discuss the outcome of the session).

Thus, the main lesson learned from KidStory with respect to the facilitation of design activities was that although a general session structure for framing the activities and creating an informal atmosphere was important, it was essential that the activities themselves were flexible and allowed for improvisation. This general approach towards orchestrating sessions was something I tried to follow in my museum work.

As described in Paper B, the four concept development sessions followed the general themes of "requirements" → brainstorming → refinement → feedback. The main goals of the sessions were:

- The first workshop would produce a number of design sensitivities that would guide the three following sessions.
- The brainstorming workshop would produce a number of initial concepts. These concepts would then be evaluated by both researchers and participants, and the design features that seemed most viable would be highlighted for refinement.
- The refinement workshop would provide additional concept details and also a number of usage scenarios.
- The final session would be used for feedback and evaluation. The outcome of the sessions would be presented to the participants, and the participants would be given an opportunity to provide feedback on the session activities.

This approach appeared to provide the necessary structure, but also allowed for improvisation. As in KidStory, an introductory and a final activity were used to outline the activities of each session and to create an "allowing" and informal atmosphere. Because the number of sessions was small compared to KidStory, there was little time to develop a "shared language". However, most of the participants had met each other before during the educational activities at the museum. Also, several members of the museum staff were educators and were used to working with children and young adults. As described in Paper B, the coffee breaks that separated the different session activities appeared to be important. Not only did they provide for rest and relaxation but they also allowed the participants to get to know one another better, which most probably made the communication between the participants less challenging.

Group processes also appeared to shape the content. For example, two of the three groups formulated a set of design tasks and divided the work between them. However, this division of labour also excluded some of the group members from the general design discussions, since they were busy elsewhere. The way the work materials were made available to the groups also appeared to influence the outcome of the brainstorming session. For example, one of the three groups chose to work exclusively with pen and paper, and the reason appears to be that the group was sitting at a table that was far from the boxes that contained the work material.

The evaluation workshops described in Paper C were also shaped by the practical circumstances of the sessions. As described in Taxén (2003), the *Well of Inventions* did not work properly when it was presented to the first group of participants: due to a programming bug, the motion of the cursors in the table projection was "inverted" with respect to the motion of the user interface devices. This inconsistency was one of the most frequently mentioned problems of the exhibition during the discussions and also appeared in several of the Post-It notes.

Perspective 3: Managing power structures between visitor and designer

The third perspective on user involvement in museum exhibition design I wish to address is concerned with power structures between visitors and "professionals".

One of the most important challenges for any participatory design methodology is how to encourage the development of "appropriate" social structures between users and the other members of the design team so that neither users nor "professionals" are completely in charge of the design (see, e.g., Alborzi et al., 2000). As described in Paper A, KidStory spent a relatively long time negotiating such a power structure between children, teachers, and researchers. One of the reasons for this was that the children were young, which made the development of a "shared language" between children and adults difficult and time consuming. Another reason was that the children had never been given an opportunity to influence the design of technology directly. Differences in the researchers' interpretations of the goals of the project also led to difficulties with managing power structures. For example, a continuing debate among the researchers concerned how much the children should be allowed to influence the choice of technologies for the prototypes, since the children's preferences did not always match the technical goals of the project. In these situations, it was necessary to attempt to value the knowledge contributions related to design methodology in relation to the knowledge contributions related to technology.

The visitor participants in my museum exhibition concept workshops were much older, and they had already been involved in educational activities with museum staff. Thus, the development of a "shared language" appeared to be less of a problem than in KidStory. However, a central challenge was that there was very little time available for negotiating a power structure between visitors and museum staff members. As reported in Paper B, this lack of time resulted in a tendency of the museum staff members to exert too much control over the general direction of the work. Consequently, it was necessary for the session facilitators to intervene on several occasions during the brainstorming. This appeared to be less of a problem in the refinement session, however.

A related issue is *how visitors see the relationship between themselves and "professionals" (including researchers)*. An important goal of the final feedback session described in Paper B was to begin to address this issue. I chose to approach the issue by focusing on *how the visitors felt about their participation in the design activities*. Thus, I asked them to evaluate the sessions in the same way as they evaluated the exhibition at the Vasa Museum. The comments were then coded and organized into concept categories. Interestingly, the data contained information not only about the sessions themselves but also about the way the design activities "meshed" with activities in other domains (in this case, the school).

Perspective 4: Using participatory design within established exhibition design practices

The final perspective emphasizes the way in which the participatory design activities presented in this thesis have been combined with "standard" exhibition production activities.

As described in the introduction, CID's collaboration with the Museum of Science and Technology, the Vasa Museum, and Swedish Travelling Exhibitions has been very different. CID was introduced to the Museum of Science and Technology through a rather long process that involved joint work on several different productions. A common feature of all of these productions, however, is that CID was able to work freely with respect to technology, design, and design methodology. One reason why this was possible was probably because CID provided its own economical resources for each production. Furthermore, the museum appears to be of the general opinion that most (if not all) examples of interesting modern technology are suitable for exhibiting at Teknorama. Thus, *exhibiting the technology itself* was always an interest, in addition to the explicit goals of each exhibit.

CID's collaboration with the Vasa Museum and Swedish Travelling Exhibitions involved exhibitions that were in the early stages of production, and the overall goals and production methods of these exhibitions were already determined to a large extent. The difference between the two collaborations, however, was that in the case of the Vasa Museum, CID was able to *find a "subset" of the exhibition to work with*, a "subset" where the producer felt that CID clearly would be able to contribute, and where it was possible to allow CID to choose their own work methods. Furthermore, the time scale and the budgetary circumstances of the project was such that CID's efforts could be treated as a trial; that is, from the museum's perspective, *it did not really matter whether the outcome of CID's work was useful to the project or not*. In the case of Swedish Travelling Exhibitions, however, the production was designed in such a way that it became impossible for CID to contribute; the work methods that CID advocated were incompatible with the work methods already chosen for the production. Because of the difficulties of communication between me and the producer, it also became impossible to find a "subset" that CID could work with independently.

To summarize, it appears that the collaboration between CID and the three industrial partners worked best when the means were available for organizing the projects so that CID's work was "safe"; that is, that CID's experiments *did not risk threatening any "regular" productions or the way such productions were developed*. Another factor that appears to have been important is *dissemination*; that is, whether the industrial partners were able to *assimilate the information they received that described previous results from CID's work*. It is interesting to note that in most participatory design methodologies, activities devoted to building confidence and developing a shared language appear to be essential (e.g., Muller, 2003). Here, however, the focus is not on an artefact or a product, but rather on the *collaboration between organizations*. The challenge, it seems, is *how to negotiate a shared understanding of what the purposes of the participatory methodologies are*, and how the methodologies could be support the existing activities of the organization in question (see Balka, 1995, or Merkel et al., 2004, for similar lines of reasoning). How such activities should be managed within the museum context is a possible subject for future studies.

Research question 2: Supporting and orchestrating learning-related social activities in museum exhibitions

My second research question is concerned with how technology can be used in museum exhibitions to support and orchestrate different social activities related to learning. I have chosen to view the contributions related to learning in museums from two perspectives:

1. Learning as a foundation for the design of museum technology.
2. Technologies for supporting and orchestrating learning-related activities.

The following sections describe these perspectives in further detail.

Perspective 1: Learning as a foundation for the design of museum technology

As discussed in the Introduction, it appears that many museum exhibition designers are influenced by different constructivist epistemologies. Constructivists, as described in Paper D, tend to see learning as a process of active individual construction that occurs when the learner is engaged in a social practice, frequently while interacting with others. For museum exhibition design, such a view of learning has important consequences. Hein (1998) described the traditional view of learning in museums as the tendency to see knowledge as something which is independent of learners, that is, learning is an incremental activity that adds facts incrementally to the minds of learners. Exhibitions inspired by such epistemologies, according to Hein, are typically sequential with panels and labels that describe what is to be learned from each exhibit. They also tend to reward "appropriate" learner activities, for example, through positive responses ("Yes, that's right!") when the learner has made the "correct" choice in an interactive exhibit.

However, museum learning research has shown that even if an exhibition is given a specific theme and is organized along the principles outlined above, visitors tend to interpret what they encounter differently, often in ways that are in direct conflict with the exhibition theme (ibid., p. 35). According to Hein, constructivists tend to argue that the reason is that learners will *always* construct personal knowledge and interpret their experiences individually, regardless of the "constraints" that may have been designed into such exhibitions. Consequently, exhibitions inspired by constructivist views of learning typically attempts to provide visitors with ways of *validating their personal conclusions*, regardless of whether these conclusions match the theme of the exhibition or not. Often, such exhibitions have several entry points (that is, they are not ordered according to the principle of beginning-middle-end); offer a range of activities, present a number of different (often opposing) perspectives of the content; and provide opportunities for creativity, experimentation, and discovery. In particular, exhibitions designed according to constructivist principles are likely to provide opportunities for interpreting objects and exhibits in different ways and provide a range of different "truths" about the content.

From a paedagogical perspective, the exhibitions and exhibits described in this thesis can be seen as being designed with constructivist-oriented principles in mind. It is important to note that I am in no position to argue that constructivist epistemologies represent the truth of how learning takes place in museums (in the ontological sense). I rather tend to view constructivism as an interesting philosophy for guiding the design of exhibitions. In other words, the learning-related contributions of this thesis should not be seen as an assessment of the nature of learning that takes place in museum exhibitions. Nor should they be seen as the "correct" way of designing technology for supporting learning in museums. Rather, they should be seen as *examples of how constructivist philosophies and epistemologies can provide novel approaches to exhibition technology*.

The papers discuss two different such approaches to exhibition design. The first approach, which is described in Papers C and E, is an attempt at *using technology to encourage collaboration and dialogue between co-present visitors*. The second approach, which is described in Paper F, is an attempt at *using technology to provide opportunities for visitors to create a dynamic and evolving context for a set of existing exhibits*.

Encouraging collaboration and dialogue

Papers C and E are concerned with the relationship between two exhibits, *ToneTable* and the *Well of Inventions*. As described in Paper E, *ToneTable* is an attempt at responding to two *design sensitivities*: 1) multiple forms of participation, and 2) interaction and co-participation. From a constructivist point of view, these two sensitivities are important concerns for museum exhibition design. As outlined above and in Paper D, visitors employ different strategies in interpretation and interaction. Designing for multiple forms of participation in museums allows for visitors to employ several different such strategies. Furthermore, constructivists tend to see personal knowledge *corroborated by others* as fundamental for learning. In museums, learning through observation and imitation appears to be very frequent, especially in connection with interactive exhibits (Falk and Dierking, 2000, p. 49–50; Hindmarsh et al., 2002). The outcomes of learning may also differ significantly depending upon whether the motivation to learn is *extrinsic* (that is, anticipated benefits are external to the activity) or *intrinsic* (that is, an action is done for its own sake). For example, the work of psychologist Mihaly Csikszentmihalyi suggests that most people exhibit a common set of behaviours and outcomes when they are engaged in free-choice tasks. They typically state that what keeps them involved is an inherent quality of the experience that Csikszentmihalyi calls *flow*. It is characterized by clear goals and immediate unambiguous feedback and tends to occur when the opportunities for action in a situation are in balance with the person's abilities (Csikszentmihalyi, 1990: Csikszentmihalyi and Hermanson, 1994).

As described in Papers C and E, the design of *ToneTable* responds to these design sensitivities by incorporating a number of features. Different *layers of noticeability*, *varieties of behaviour*, and *structures of motivation* were used to make the exploration of *ToneTable* an open-ended affair and allow the installation to be explored over various time-scales. Collaboration and coordination between visitors were supported by providing opportunities for interacting through a *shared virtual medium* (in this case an animated water-like surface) and were encouraged through *emergent collaborative value*. Furthermore, by designing *ToneTable* to be "*abstract, yet suggestive*", the installation did not impose any particular paedagogy or approach towards interpretation.

As described in Paper E, I tried to retain these features when *ToneTable* was subsequently redesigned to become the *Well of Inventions*. However, because of its intended location in the Museum of Science and Technology – the Teknorama science centre – I felt that it was important that the content of the new installation be less abstract. Consequently, I let the nature of the museum inspire a theme (that of dynamics, machinery, and conversion of energy) and tried to incorporate it into the design. As described in Papers C and E, the result was an installation that appeared to encourage similar types of behaviour as those in *ToneTable*, including collaboration and coordination.

However, while it was quite clear that visitors discussed the exhibition and constructed their own interpretations of it (for example, young children would be fascinated by the virtual water surface while older children would treat the installation as an interactive game), these interpretations did not match the kinds of interpretations I had envisioned when designing the installation. Interestingly, although many visitors appeared to enjoy interacting with the installation, many also appeared to express a frustration over not understanding its purpose, something which appeared to be less of a concern for users of *ToneTable*. In my interpretation, this is due to the context in which the *Well of Inventions* was exhibited. Teknorama, as most science centres, is designed to encourage a "paedagogical" approach towards interpretation and does so through a number of different design conventions. For example, most exhibits are "experimental" in nature (that is, they pose a question and invite visitors to experiment to find the answer), different groups of exhibits relate to different themes from the natural sciences, many labels contain both usage instructions and background information, and so on. I believe that because the *Well of Inventions* followed very few of these conventions, the exhibition came across as "strange". *ToneTable*, on the other hand, was exhibited in locations that did not frame visitors' expectations in this way. Consequently, one of the important results of the *ToneTable/Well of Inventions* experiment is that although the approach towards encouraging collaboration and dialogue between visitors appeared to work quite well, *the nature of the context in which the exhibits were situated had a fundamental impact on the way they were interpreted by visitors.*

Evolving context

Paper F describes an attempt at using technology to allow visitors to interactively create a dynamic and evolving context for a set of existing exhibits in Teknorama called the *Mighty Five*. These exhibits illustrate five mechanical principles: the screw, the plane slope, the lever, the wheel, and the wedge. The museum's own evaluation of these exhibits suggests that many visitors fail to grasp the way they relate to one another (that is, that they constitute a set of different, yet interrelated mechanical principles). Consequently, an important goal for the project was to see whether exhibiting examples of how the *Mighty Five* principles have been embodied in different artefacts outside the museum had the ability to support the conceptual integration of the existing exhibits.

Another goal for the project was to see whether it was possible to use modern communications technology to document the nature in which visitors relate their museum experiences to experiences of similar principles outside the museum. According to Falk and Dierking (2000), it appears that many people draw conclusions that are related to their visit later, *outside* the museum, when they encounter a situation that allows them to "make a connection" with something they have experienced in the exhibitions. Documenting these situations is, naturally, quite difficult. Falk and Dierking mention a number of studies where researchers have telephoned visitors some time after the visit and asked them to recall the museum visit and how it has shaped later encounters and experiences. Although important and valid, these data consists of the learners' recollection of their experiences and there are typically no data from the actual situation itself.

As described in Paper F, the exhibit was partially successful. There is evidence that it indeed provided opportunities for visitors to interrelate the different *Mighty Five* exhibits. However, all attempts at encouraging visitors to contribute with data for the exhibit from outside the museum failed, which prompted me to look for ways in which to encourage visitors *in* the museum to contribute. The outcome was a set of different "treasure hunts", that is, didactical activities (largely designed by a member of the museum's paedagogical staff). At the time of writing, these "treasure hunts" have been carried out successfully with a number of children between 8 and 12 years old.

From a learning perspective, I believe the project described in Paper F had two important outcomes. The first is that *the approach towards using technology to provide a context for the* Mighty Five *appeared to be largely successful* in the sense that there is evidence that visitors used the new exhibit to relate to the other *Mighty Five* exhibits. The second is an account of *how different activities in museums can be used to appropriate technology for educational purposes it was not initially designed for*. For example, I have used the wooden block user interface of the exhibit to illustrate the concept of Radio Frequency Identification (RFID) tagging to visitors. Another example is how the "treasure hunt" activities made use of the book roll.

Perspective 2: Technologies for supporting learning-related activities in museums

The second perspective is concerned with the technology itself – which technologies can be used to support learning-related activities, and how?

Many of the technologies described in this thesis are examples of *mixed-reality technologies*. Within HCI, mixed reality is often seen as the "gap" between virtual reality and ubiquitous computing, that is, the goal is not merely to embed technology in everyday physical objects (as it is in much of ubiquitous computing) or to construct digital environments of different sorts (as in virtual reality). Rather, mixed-reality is concerned with *hybridized digital presentations*, that is, digital presentations that are overlaid and juxtaposed with physical-digital objects.

For example, Paper E describes how both *ToneTable* and the *Well of Inventions* explored different interrelationships between table-based projections and sound environments, while Paper F describes how wooden blocks with digital properties can be used as an interface for a "digital book roll".

Another general approach towards technology design that underpins much of the work in this thesis is the support of *multiple co-present participants*. For example, the *KidPad* drawing tool described in Paper A was based upon the notion of multiple co-present users. This notion was also a fundamental design concern for both *ToneTable* and the *Well of Inventions,* which allowed multiple visitors to interact simultaneously through the use of trackballs (indeed, *KidPad* and the two installations made use of the same programming library for supporting multiple input devices). Furthermore, as described in Paper E, orchestrating the activities around a table (or a "digital book roll" in the case of the *Mighty Five*) naturally allowed for gesturing, coordination, and turn-taking.

My personal contribution to the technology presented in the papers is largely related to different kinds of graphical presentations. For example, I programmed a substantial number of the *KidPad* tools and provided the graphics for *ToneTable*, the *Well of Inventions*, and the *Mighty Five* book roll. Furthermore, I have also been involved in providing underlying systems support. For example, the *Well of Inventions* and the *Mighty Five* exhibits are built upon a toolkit I wrote called *Wasa*. As described in Paper D, the toolkit has also been used in other circumstances, such as education and virtual reality research. As indicated in Paper C, the toolkit also contains implementations of a number of simulation algorithms. Examples include the rigid body dynamics and fluid flow algorithms used in the *Well of Inventions*.

Summary

The first of the two research questions raised in this thesis is:

- How can knowledge of participatory design within HCI be applied in the museum domain to include visitors in the design and evaluation of exhibitions?

In the account above, I have approached this question from four different perspectives. The first perspective focused on issues such as:

- Why should visitors contribute to museum exhibition design?
- How can they contribute?
- When can they contribute?
- Who should participate?

The second perspective focused on issues such as:

- How can the visitor contribution be managed?
- How can design and evaluation sessions be orchestrated?

The third perspective focused on issues such as:

- How can a fruitful dialogue between visitors and exhibition designers be facilitated?

The fourth perspective focused on issues such as:

- What consequences does involving visitors have with respect to the exhibition producers' current design practices?

I believe the papers on which this thesis is based provide a starting point for a discussion of these issues. I would argue that my work suggests that involving visitors in exhibition design can indeed be fruitful: the experiments with concept development and evaluation described in Papers B and C provided relevant information from visitors that I believe may have been difficult to obtain through "standard" museum design and evaluation activities alone. I also believe that it is clear that visitors *can* contribute to all four phases of museum exhibition design.

Papers A, B, and C also provide a number of examples of how visitor participation can be managed and orchestrated. Papers B, C, and F also suggest different ways in which visitor contributions can be incorporated into an exhibition production.

The issue of how to assess the outcomes of visitor participation in museum design is also an issue that is partly addressed by my work. In Papers B and C, the outcome of the design process is evaluated with respect to *relevance*, that is, whether the sessions provided information that might be useful to the museum. However, Paper B also argues that assessment should not only be carried out from the researcher's perspective: determining whether the *participants* believe that the design activities are fruitful or not is important too. Paper B also provides an example of how such a "participatory" assessment can be made.

Chapter 3 raises the question of how to introduce the concept of user-oriented design within exhibition-producing organizations. In my opinion, the analysis suggests that the manner in which such methodologies are advocated is of primary importance. If this is not done in an appropriate way, it may be impossible to develop a shared understanding of how and when the methodologies are to be applied. It is also important that such discussions are held at the appropriate time – if a general approach towards design has already been established within a project, it may be difficult (or even impossible) to introduce user-oriented methodologies later if they do not "match" the project's approach.

The second of the two research questions raised in this thesis is:

- How can technology be used in museum exhibitions to support and orchestrate different social activities related to learning?

In the account above, I have approached this question from two different perspectives. The first perspective focused on issues such as:

- Why should learning be used as a foundation of museum exhibition design?
- How can it be done?

The second perspective focused on issues such as:

- Which technologies could be used to support and orchestrate learning activities in museums?
- How can they be used?

I believe the papers included in the thesis provide several examples of how constructivist perspectives of learning can inspire novel designs of museum exhibition technology. All of these exhibition designs have proven to be rather flexible and support multiple forms of interpretations. From a constructivist point of view, the "story" of exhibitions is seen as having less importance than it would have had from more "traditional" perspectives. Rather, the primary concern is the way visitors encounter artefacts in museums and the different ways in which these artefacts can be interpreted and understood, both in isolation and in relation to other artefacts. I would argue that this thesis provides a number of novel ways in which technology can be used to support and encourage such activities.

I am also of the opinion that, when taken together, the different projects described in this thesis suggest that mixed-reality technology holds great potential for museum exhibitions. Clearly, the technology can be used to support open-ended experiences with many opportunities for personal interpretation. Furthermore, as described in Fraser et al. (2004), the technology also holds the potential to allow visitors to *focus on the museum* *artefacts rather than on the technology itself*, which is of primary concern to many museums today (e.g., vom Lehn & Heath, 2003).

However, the "failures" described in Papers C, E, and F also raises a number of concerns. First of all, constructivism is not an uncontroversial philosophy of learning. Indeed, as described in Paper D, it has been heavily criticized, both with respect to its philosophical (e.g., Weinberg, 1998) and epistemological and psychological (e.g., Anderson et al., 1996) roots. The critics' main concern is the tendency among many constructivist-oriented paedagogical practitioners to overemphasize aspects of the constructivist stance. Within the museum domain, such an overemphasis might, for example, lead to cultural heritage exhibitions that refrain from providing any factual information at all, that is, where *everything* is open to interpretation. Clearly, such exhibitions would be in conflict with the basic paedagogical goals of most museums. Another issue is how visitors relate to constructivism-inspired exhibitions, especially in situations where they appear to be in conflict with the way other exhibitions in the same museum have been designed.

5. Conclusions

This thesis is concerned with the design of technology for museum exhibitions. More specifically, it explores different ways in which visitors can contribute to museum exhibition design (including technology) and how technology can support learning-related activities within museum exhibitions. This chapter summarizes the results and provides some directions for future research.

Participatory design of museum exhibitions

Most contemporary museums collect, preserve, and provide access to important cultural and historical artefacts with the explicit intention of educating and informing the general public about those artefacts. For many exhibition designers, the audience's encounter with the exhibition is of primary concern, and technology is often seen as a means for providing visitors with new experiences and opportunities for learning. However, it appears to be only recently that researchers have begun to show an interest in how modern technology *is actually being used by visitors* and many museums are struggling in their efforts to take new technologies into account in their established exhibition design practices. As argued in the introduction, HCI has the opportunity to provide museums with *new ways for audiences to contribute to exhibitions with their knowledge, experience, opinions, and desires*. Consequently, the first research question I have attempted to answer is:

- How can knowledge of participatory design within HCI be applied in the museum domain to include visitors in the design and evaluation of exhibitions?

Papers A, B, and C provide examples of how participatory design methodologies developed within HCI can be adapted for museums and how these adapted methodologies can be used to involve visitors in the design and evaluation of exhibitions.

Most exhibition projects have four phases: 1) a *conceptual phase* where ideas for the exhibition are developed into some sort of description, 2) a *development phase* where the description is implemented, 3) a *functional phase* when the exhibition is on display, and 4) an *assessment phase* when the exhibition and the production are evaluated. The work presented in this thesis targets the conceptual, functional, and assessment phases (user involvement during the development phase appears to be well-covered by existing practices).

Conceptual phase: participatory exhibition concept development

I have designed, organized, and hosted a series of workshops where a number of museum educators and curators worked together with representatives of one of the target groups of a new exhibition. First, the representatives evaluated the current exhibitions at the museum, which resulted in a set of "design sensitivities" that guided the rest of the work. Two sessions followed in which the participants worked together to develop and refine concepts for the new exhibition. The final session was devoted to feedback: I provided the participants with an overview of how their concepts related to current trends within museum research, and the participants provided me with their opinions on the work methodology itself. The outcome of the design activities was three detailed exhibition concepts with a number of interesting technological and paedagogical features. These features were also relevant in the sense that they addressed current issues within museum technology research.

Functional phase: visitor contributions to museum exhibitions

It is not uncommon that visitors are invited to provide content for museum exhibitions, either through material collected by the design team during the conceptual and development phases of exhibition design or while the exhibition is on display. The thesis provides a new approach towards collecting material from visitors, an approach that allows contributions from *unspecified locations* both inside and outside the museum. The approach has been implemented in an exhibition where the primary function is to present the visitors' own interpretation of the different museum artefacts they encountered during their visit (and elsewhere). Thus, the exhibition represents a collective interpretation that is allowed to change and evolve while the exhibition is on display.

Assessment phase: participatory evaluation of exhibitions

Most museum exhibitions are evaluated in some way, and a number of established methodologies are available. The thesis contains a description of how data from such an evaluation were compared to data generated through a series of workshops, which I designed, organized, and hosted. The main goal for these workshops was to provide an opportunity for visitors to provide direct feedback to the exhibition designers with a particular focus on *generating ideas for improving the exhibition*. In terms of participatory design, the exhibition was seen as a prototype, and the workshops were designed to provide ideas for refinement. The data comparison suggests that, to a large extent, the workshops raised the same issues as did the other forms of evaluation. Thus, the workshops were able to provide relevant evaluation data. But in addition, the workshops also provided numerous design ideas for improving the exhibition.

Technology for supporting learning-related activities in museums

Another line of questioning I have followed is concerned with *how technology can be used to support learning-related activities in museums*. Education and learning is of primary concern to most museums, and many museums base their notion of learning on constructivist epistemologies. These epistemologies, in turn, suggest certain types of activities in museums as more important than others for supporting learning, such as interpretation, communication, and collaboration. Thus, the second research question I have attempted to address in this thesis is:

- How can technology be used in museum exhibitions to support and orchestrate different social activities related to learning?

Papers D, E, and F provide examples of how mixed-reality technologies can be used to encourage collaboration and dialogue and to provide opportunities for shaping the context of museum exhibits.

Encouraging collaboration and dialogue in museum exhibitions

The part of this thesis that is concerned with learning examines the relationship between two exhibits, *ToneTable* and the *Well of Inventions*, in some detail. *ToneTable* is an attempt at responding to two *design sensitivities*: 1) multiple forms of participation and 2) interaction and co-participation. From a constructivist point of view, these two sensitivities are important concerns for museum exhibition design. Visitors employ different strategies towards interpretation and interaction, and designing for multiple forms of participation in museums allows for visitors to employ several different such strategies. Furthermore, constructivists tend to see personal knowledge *corroborated by others* as fundamental for learning. In museums, learning through observation and imitation appears to be frequent, especially in connection with interactive exhibits.

The design of *ToneTable* responds to these design sensitivities by incorporating a number of features. Different *layers of noticeability*, *varieties of behaviour*, and *structures of motivation* were used to make the exploration of *ToneTable* an open-ended affair and allow the installation to be explored over various timescales. Collaboration and coordination between visitors were supported by providing opportunities for interacting through a *shared virtual medium* (in this case an animated, water-like surface) and was encouraged through *emergent collaborative value*. Furthermore, by designing *ToneTable* to be "*abstract, yet suggestive*", the installation did not impose any particular paedagogy or approach towards interpretation.

When *ToneTable* was subsequently redesigned to become the *Well of Inventions*, the intention was to retain these features. However, because of the intended location of the new exhibition (a science centre), the content was modified to become less abstract. The nature of the museum inspired a theme (that of dynamics, machinery, and conversion of energy) which was incorporated into the design. The result was an installation that encouraged similar types of behaviour as *ToneTable*, including collaboration and coordination.

However, while it was quite clear that visitors discussed the exhibition and constructed their own interpretations of it, these interpretations did not match those originally expected. Although many visitors appeared to enjoy interacting with the installation, many also appeared to express a frustration over not understanding its purpose, something which appeared to be less of a concern for users of *ToneTable*. One reason for this is probably the context in which the *Well of Inventions* was exhibited. The science centre is built around a "paedagogical" approach towards interpretation, and because the *Well of Inventions* followed very few of the conventions associated with this approach, the exhibition came across as "strange". *ToneTable*, on the other hand, was exhibited in locations that did not frame visitors' expectations in such a way. Consequently, one of the important results of the *ToneTable*/*Well of Inventions* experiment is that although the approach towards encouraging collaboration and dialogue between visitors appeared to work quite well, the nature of the context in which the exhibits were situated had a fundamental impact on the way they were interpreted by visitors.

Evolving contexts

The thesis also describes an attempt at using mixed-reality technology to allow visitors to interactively create a dynamic and evolving context for a set of existing museum exhibits called the *Mighty Five*. These exhibits illustrate five mechanical principles: the screw, the plane slope, the lever, the wheel and the wedge. The museum's own evaluation of these exhibits suggests that many visitors fail to grasp the way they relate to one another (that is, that they constitute a set of different, yet interrelated mechanical principles). Consequently, an important goal was to see whether exhibiting examples of how the *Mighty Five* principles have been embodied in different artefacts outside the museum had the ability to support the conceptual integration of the existing exhibits.

Another goal was to see whether it was possible to use modern communications technology to document the nature in which visitors relate their museum experiences to experiences of a similar nature outside the museum. Many people draw conclusions that are related to their visit *outside* the museum, after the visit, when they encounter a situation that allows them to "make a connection". Documenting these situations is, naturally, quite difficult. Obviously, it is possible to telephone visitors some time after their visit and ask them to recall how the visit shaped later encounters and experiences. However, these data consist of the learners' recollection of their experiences and there are typically no data from the actual situation itself.

The experiment was partially successful. There is evidence that the new mixed-reality technology indeed provided opportunities for visitors to interrelate the different *Mighty Five* exhibits. However, all attempts at encouraging visitors to contribute data for the exhibit from outside the museum failed, which prompted me to look for ways in which to encourage visitors *in* the museum to contribute. The outcome was a set of different "treasure hunts", that is, didactical activities where visitors would search the museum for machinery that embodies the principles of the *Mighty Five* exhibits.

From a learning perspective, the experiment had two important outcomes. The first is that the approach towards using technology to provide a context for the *Mighty Five* appeared to be largely successful in the sense that there is evidence that visitors used the new technology to relate to the other exhibits. The second is an account of how different activities in museums can be used to appropriate technology for educational purposes it was not initially designed for.

A visitor-oriented perspective on exhibition design

As mentioned in the Introduction, my research questions can be seen as representing two different, yet interrelated perspectives on museum exhibition design. From the first perspective, visitors' desires, wishes, experiences, and knowledge are seen as important contributions to museum exhibition design. From the second perspective, different social activities and relationships between visitors in museums become the focus of the design activities. Together, these two perspectives outline an approach to museum exhibition design where *visitors are of primary concern*, both with respect to the content presented in exhibitions and with respect to the way exhibitions orchestrate and support different forms of social interaction.

Future work

The knowledge contributions in this thesis are exploratory and (to a certain extent) explanatory in nature. In other words, the results should not be seen as normative or predictive. Nor are the results generalizable in the statistical sense. Whether they are *transferable* to other situations, however, is an issue that would be interesting to consider in future research. I would argue that the general methodology and approaches to technology design presented in the papers are *repeatable*, which makes them possible to study in other contexts. For example, it would be interesting to analyse the outcome of applying a visitor-oriented perspective throughout all four phases of an exhibition production.

Another interesting set of issues concerns the combination and integration of design methodologies from different communities of practice. Within HCI, such integrations have been shown to be fruitful in the past. Indeed, the entire user-oriented design movement is founded upon the assumption that collaboration between users and computer system designers has the ability to produce "better" systems than those developed by computer system designers alone. The question is whether this is the case for the museum domain as well.

This obviously raises questions related to quality and the assessment of quality. That is, how should one assess whether an exhibition is successful or not? An exhibition that is groundbreaking from, say, an artistic or technical perspective may be rejected completely by its audience. Conversely, a highly popular exhibition may be totally unsuitable from, say, a paedagogical point of view.

Furthermore, is the concept of usability transferable to museum technology? Surely, a user interface for a piece of technology in a museum may be more or less easy or pleasant to use, but what about *usefulness*? Is there a corresponding term for museum exhibition design? If so, how does one measure it? Today, many museums measure quantitative data such as visitor attendance figures and dwell times, but the question is whether such data provide all the relevant details (c.f., Dicks, 2002 for a similar line of reasoning from an HCI perspective).

Final thoughts

As mentioned in the Introduction, many cultural heritage museums (both in Sweden and abroad) are questioning their "traditional" task of providing the public with unquestionable historical "truths". Instead, they tend to work towards more multifaceted and open-ended exhibition design ideals that challenge the more authoritative, structured paedagogical conventions of the past. One aspect of this trend is that many museum exhibition producers have begun to shift their focus from content to physical form. Unlike the director in theatre or cinema who uses written text as a foundation for his or her work, many exhibition producers now appear to consider the exhibition's visual (and auditive) expression in physical space before considering the content (Persson, 1995). In other words, the "story" is less of a priority than the "shape". As a result, many cultural heritage museums have begun to commission interpretations of their collections from professional artists or exhibit contemporary art outright. Examples range from Fred Wilson's controversial treatments of existing museum collections, to the provocative exhibitions of cultural history at the Musée d'ethnographie in Neuchâtel. Some museums, such as the Hedmark Museum in Hamar, have chosen to go so far as to remove most (or even all) written information from their exhibitions and let the form, shape, and material of the artefacts become the focus of attention.

Obviously, this raises the question of what role a visitor-oriented perspective can play in contemporary exhibition design. When an exhibition design project is built around one or several artists, direct contributions from "ordinary people" may simply not be relevant (as illustrated by the analysis in Chapter 3 above).

A common misunderstanding of user-oriented design is that it advocates that users should "dictate everything". This is simply not true. Rather, it is about allowing users' opinions to *influence* the outcome of the design project. The question is *to what extent* and *in what way* this should be done. Consequently, I am not of the opinion that "ordinary people" should replace the work of professional designers or artists in museum exhibition design. Rather, I'm raising the question of whether artistry is the *only way* in which the traditional, authoritative way of making exhibitions can be challenged. In my opinion, shifting the precedence of interpretation from the curator, educationalist, or subject specialist to a professional artist does not *necessarily* result in a multifaceted, open-ended exhibition simply because artists are typically commissioned to provide their *personal* interpretation of the material at hand. Clearly, such a personal interpretation has the potential to illustrate that it is *possible* to see the material from other perspectives than those offered by a "traditional" exhibition (and artists are indeed normally very good at providing alternative perspectives). But it does not automatically follow that the artist's rendition *allows for other interpretations than his or her own*.

Ultimately, I believe that the issue is what role the cultural heritage museum should play in today's society. In what ways should our cultural heritage be collected, researched, interpreted and exhibited? For me, it is obvious that this is a discussion in which everyone should be allowed to participate, regardless of whether one is an exhibition producer, an artist, a subject specialist, or an "ordinary person". Unfortunately, "non-professionals" are rarely invited to take part in the cultural debate on museums. A visitor-oriented perspective on exhibition design could be one way of facilitating such participation.

The original aim of the cooperative design projects in Scandinavia was to democratize the workplace. It is my hope that the work presented in this thesis can be the starting point of a discussion of the democratization of the museum.

G.T.
2005-04-02

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Appendix A – Concepts and relations

This appendix contains the concepts and relations described in Chapter 3.

List of concepts

Words in *italic* in the descriptions denote concepts that can be found elsewhere in the list. In the **Grounded in** column, I1 denotes interview 1 and I2 denotes interview 2. The time indicates the position in the sound file where the dialogue about the concept begins. (The interviewee did not allow me to use quotes.) Some concepts are grounded in other forms of data, for example, implied by the organization of the project, things said at meetings, things said during my visits to Swedish Travelling Exhibitions (STE), the STE website, and formal documents, and this is indicated where applicable.

Concept	Description	Grounded in
Artistic leadership	To make sure that STE's *exhibitions* are coherent, respond to current important societal issues.	I2: 33:29
Artistic responsibility	To keep the *exhibition* together with respect to *content*, to have an overall view. The artistic responsibility is shaped by the *goals* for the *exhibition*, but also by STE's *priorities*.	I1: 18:46 I2: 15:53 I2: 17:43
Arranger	An organization or an administration of some sort that receives the *exhibition* during its *tour*.	I1: 3:40 I2: 56:04
Budget	The economical plan for the project.	I1: 17:19 I2: 9:53
Commission	The commission STE has from the *Ministry of Education*: 1) to produce *touring* exhibitions and 2) to develop the exhibition media artistically, paedagogically and technically.	I1: 9:39 I2: 9:24 Documents
Contacts	Contacts that an *external partner* may have that are considered useful to the project.	I1: 15:08
Content	The textual (linguistic) content and physical shape/form of the *exhibition*. The content is developed by the *inner creative group*, and is "converted" into an	I1: 30:02 I1: 35:09 I1: 37:50 I1: 40:00

	exhibition during the project's *implementation phase*.	I1: 48:53 I1: 53:14 I2: 25:30
Contribution	The contributions of an external partner to the project. Contributions may include active participation in the design process, consultation, guidance, etc. External partners may also contribute with *objects*, their *knowledge*, and *contacts*.	I1: 15:08
Control	The *producer* has the ability to exercise *control* over the activities of the *project team* and the *inner creative group* if the results of the work fail meet the *exhibition*'s *goals*.	I1: 41:51 I2: 17:21
Create visualization	Create a description of the physical shape/form of the *content* of the *exhibition*.	I1: 37:50
Decision	If the *director of exhibitions* is happy with a *feasibility study*, he may decide to give the go-ahead for the project.	I1: 10:57 I2: 20:24 I2: 54:50
Deputy director of exhibitions	[The role is mentioned in the data, but not described.]	I2: 7:27
Design process	The process that shapes and develops the *content* of the *exhibition*. The result of the design process is a design which can be "converted" into an *exhibition* during the project's *implementation phase*.	Project org. I2: 17:43 I2: 25:30
Director of exhibitions	The person at STE that is responsible for its *exhibitions*. The director of exhibitions provides *artistic leadership* for STE and is responsible for STE's *repertoire*.	I1: 10:20 I2: 7:27 I2: 33:29
Evaluation	Most of STE's productions are evaluated in different ways. The evaluation may focus on the *exhibition* itself, project management, and/or the *development process*.	I1: 40:40
Exhibition	The outcome of the project.	Project org.
Exhibition assistant	[The role is mentioned in the data, but not described.]	I2: 7:27
Exhibition coordinator	The person responsible for *tour planning*.	I1: 3:40 I2: 12:02 Project org. Meetings
Experience	The experience a person brings to the *project team* in general; and to the *inner creative group* in particular.	I1: 35:09 I1: 37:50 I2: 21:18

External partner	A person or a group of persons that are not normally employees of STE, which have the potential to become members of the *project team*. During the time CID was involved in *"Once upon a time..."*, the *scriptwriter*, the *set designer* and CID were external partners.	I1: 37:34 I2: 13:45 I2: 17:43 Project org.
Feasibility study	A feasibility study is a preparation for an *exhibition* project. Formally, such a study should contain a number of items, including a background, *goals* that respond to STE's *priorities*, delimitations, a description of the project group, a work plan, a description of work methods, a time plan, a *budget*, a list of potential *external partners*, *tour* prerequisites, and a marketing plan.	Project org. I2: 9:53 I2: 39:48 I2: 52:46
Financier	Organization or person that provides the financial *resources* for a project. In the case of *"Once upon a time..."*, the financier was STE itself.	I1: 7:10 I2: 9:53
Full view	If the *producer* is to be able to fulfill his/her *artistic responsibility*, he/she must have a full view of the *design process*. It is especially important that the producer has a full view of the activities of the *inner creative group*.	I1: 20:03 I2: 17:14
Goals	In the interview data, three main types of goals can be discriminated: 1) the goals of STE in general, which are interpreted as *priorities*, 2) the goals of a particular *exhibition* project, which are formulated in the *feasibility study*, and 3) the goals that are motivated (and shaped) by the *design process* (for example, the goals a certain member of the *project team* may have at a certain point during the development of the *content* of the *exhibition*).	I1: 0:18 I1: 36:09 I2: 8:55 I2: 29:23
Head of Expoteket	The person at STE that is responsible for Expoteket. Expoteket is both a library and an archive of previous *exhibitions*.	I2: 7:27 Visits WWW
Head of technology	The person at STE that is responsible for technology.	I2: 7:27 Meetings
Idea provider	A person or a group of persons that provide STE with an *initiative* for an exhibition. The idea provider is not	I1: 11:34

	necessarily an employee of STE.	
Implementation	The process by which a finished exhibition design is, through technology, "converted" into a finished *exhibition* that can be sent on tour.	Project org. I2: 15:40
Initiative	An initiative for an *exhibition* from an *idea provider*.	I1: 11:34
Inner creative group	A subset of the *project team* that is responsible for developing the *content* of the *exhibition*. The *producer*, *scriptwriter* and *set designer* were members of the inner creative group during the time CID was involved in the project.	I1: 35:09 I2: 17:43 I2: 20:31
Interests	Interests that persons that are part of the project have.	I1: 36:09 I2: 19:00
Introduction process	Processes where potential *external partners* are introduced to the *project leader* and the *producer*.	I1: 28:48 I1: 43:58 I2: 21:50
Knowledge	In the data, three different kinds of knowledge can be distinguished: 1) knowledge that is part of the *work skills* of a member of the *inner creative group*. 2) Knowledge that the *project team* develops during the project, for example, through meetings with *specialists* or the *reference group*. 3) The producer's knowledge about the *work skills* of a potential partner, developed as the result of an *introduction process*.	I1: 32:11 I1: 40:00 I2: 22:10 I2: 26:15
Material	Different sorts of (physical) material gathered during the *reference group meetings*, for inclusion in the *exhibition*. This material shapes the *content* of the *exhibition*.	I1: 32:11 I2: 26:15
Meetings with specialists	Meetings with specialists that take place either during the *feasibility study phase* or the *design phase* of the project. The main goal of these meetings is to draw upon the specialists' *knowledge*.	I1: 40:00 I2: 11:00 I2: 54:12
Ministry of Education	A ministry that is part of the Swedish government that provides a *commission* for STE.	I1: 9:39 I2: 8:55
Mobile space	A large truck made especially for transporting and hosting *touring exhibitions*. When arriving at a site, the truck bed is converted into a room	Project org. Meetings E-mails Documents

	(roughly 90 square meters in size), in which the packaged *exhibition* is then assembled. This particular mobile space was designed and built concurrently with *"Once upon a time..."*, and the exhibition is the first exhibition to be featured in it.	I1: 21:36 I2: 10:53
Objects	The objects that are exhibited in an *exhibition*.	I1: 15:08
"Once upon a time..."	The *exhibition* project CID was involved in.	Project org.
Openness	The extent to which a person allows other peoples' opinions and suggestions to influence him/her.	I1: 49:34
Participation	The extent to which an *external partner* is being allowed to participate in the *design process*.	I1: 20:03 I2: 21:18
Planned external activities	Activities that planned in conjunction with an *exhibition*'s arrival/visit at a certain site.	I2: 10:23 Documents
Priorities	The directives in STE's *commission* are interpreted by STE, which results in a number of priorities, for example, children and teenagers.	I2: 8:55 I2: 29:23
Producer	The person (an employee at STE) that has the *artistic responsibility* for the *exhibition*.	I1: 17:37 I2: 15:53 I2: 17:43
Project leader	The person (an employee at STE) responsible for meeting the project's *budget* and time plan.	I1: 16:46 I2: 12:17
Project management	The activity whereby a *project leader* guides the project, and makes sure that it meets its *budget*, and finishes on time.	I1: 16:46 I2: 12:17
Project phase	The phase the project is in when a potential *external partner* is being introduced.	I1: 33:29 I2: 22:10 I2: 39:48 I2: 46:42
Project team	The group of persons that design the *exhibition* together and make sure that it is implemented and sent on *tour*. The *project leader*, *producer*, *exhibition coordinator*, *scriptwriter*, *set designer* and *technician* were members of the project group during the time CID was involved in the project. Gustav Taxén from CID was also a member of the project team during this	I1: 19:39 I2: 20:28 Project org.

	time.	
Proposal	A document that proposes a theme for an *exhibition*.	I1: 11:34
Recipient	A person that *visits* the *exhibition*.	I1: 41:07 I1: 57:25 I1: 59:05
Reference group	A subset of the target group of the *exhibition*. In *"Once upon a time..."*, the target group were children, 11-13 years old, that live in Swedish cities where many different languages are spoken.	I1: 30:27 I2: 26:15
Reference group meeting	Occasions when persons in the *inner creative group* meet the *reference group*. The goal of these meetings is mainly to acquire *knowledge* about the *reference group*, but the meetings could also be used to gather *material* for the *exhibition*, or for *testing* ideas and concepts developed by the *inner creative group*.	I1: 32:11 I2: 26:15 I2: 41:21
Repertoire	The set of *exhibitions* that STE have to "offer" at a given time.	I1: 10:20
Report back	The *commission* STE has from the *Ministry of Education* requires STE to report back on how STE has dealt with equal opportunities, environmental issues, availability, etc.	I1: 9:39 I2: 29:41
Resources	The economical means used to finance an *exhibition*.	I1: 7:10 I2: 9:53
Responsible for feasibility study	The person that is responsible for the *feasibility study*. This may or may not be the same person that becomes *project leader* if the project is given the go-ahead.	I2: 52:46
Role	To be responsible for something in the project. In the data, two different types of role can be distinguished: "administrative" roles such as the *project leader*, and "creative" roles such as the *scriptwriter*.	I1: 20:03 I1: 30:02 I2: 22:45
Screening	An initial selection process where those *proposals* that do not address STE's general *goals*, are not feasible, or otherwise unsuitable are rejected.	I1: 10:57 I2: 8:14
Scriptwriter	The person responsible for developing the textual/linguistic *content* of the *exhibition*.	I1: 37:50 I2: 54:55
Security	Whether or not the *producer* feels secure	I1: 20:03

	with respect to the current status of the project, or with respect to potential *external partners*.	I2: 22:45 I2: 36:13
Selection	The *director of exhibitions* makes a selection of projects based upon whether they address STE's *priorities*, whether they have artistic merit, and whether they fit STE's *repertoire*.	I1: 10:20
Set designer	The person responsible for developing the physical shape/form of the *content* of *Once upon a time...*	I1: 37:50
Specialist	A person or a group of persons that are not employees of STE, nor members of the *project team*, but are nevertheless consulted at different occasions, especially during the *feasibility study*.	I1: 40:00 I2: 11:00 I2: 54:12
Successful visit	A successful visit entails a number of aspects, including that the recipient should feel motivated, feel that the *exhibition* concerns him/her, and that the *exhibition* is emotionally moving.	I1: 57:25
Suitability	Whether or not a potential *external partner* has the ability to contribute to the project. Suitability is something that the *producer* ultimately decides upon.	I1: 20:03 I1: 25:53 I2: 22:10
Technician	A person that knows technology and/or builds technology for *exhibitions*. Examples of technologies include video, audio, mechanics, and lighting.	Project org. Meetings Visits
Testing	A possible activity during *reference group meetings*, where the *inner creative group* test ideas and/or concepts that they have developed.	I1: 32:11
Tour	STE has no stationary or permanent exhibition space; all *exhibitions* are sent on tour. Some *exhibitions* are packaged and transported from site to site (for example, museums or libraries), whereas others are installed in *mobile spaces*, for example, converted train cars or trucks.	I1: 3:40 I1: 5:38 I2: 10:53 I2: 12:02 I2: 56:10
Tour planning	The activity that determines to which sites an *exhibition* is to be sent, and when.	I1: 3:40 I2: 12:02
Trust	Whether or not the *producer* feels confident enough with a partner to allow him/her/it to be given a *role* in the	I1: 20:03

	project.	
U.T.E. group	The group of persons at STE that is responsible for *screening* exhibition *proposals*.	I1: 10:57 I2: 7:27
Values	The values and frames of reference that a person acts according to.	I1: 20:03 I2: 21:30
Visit	To visit the *exhibition*.	I1: 57:25
Work method	The work methods preferred by members of the *inner creative group*.	I1: 53:53 I2: 19:12 I2: 25:30 I2: 41:21
Work skills	The work skills of a potential *external partner*. Work skills embody *experiences, openness, values and opinions, knowledge,* and *interests*.	I1: 20:03 I1: 35:09 I1: 37:50 I2: 21:30
Write manuscript	What a *scriptwriter* does.	I1: 37:50 I2: 54:55

Relations between concepts

Relations marked with an asterisk (*) are relations that, even though they are not addressed directly in the data, still follow logically from other relations and concepts. I1 denotes interview 1 and I2 denotes interview 2. The time indicates the position in the sound file where the dialogue about the concept begins. (The interviewee did not allow me to use quotes.)

Relations related to the producer

STE's commission provides priorities for the feasibility study

STE's commission from the Ministry of Education is (according to the STE website): 1) to produce touring exhibitions and 2) to develop the exhibition media artistically, paedagogically and technically. The commission requires STE to report back to the Ministry of Education on issues such as equal opportunities and availability (I2: 29:41). However, the Ministry does not directly dictate the goals of STE. Rather, STE are free to interpret its commission (I1: 9:39). The interpretation leads to a number of priorities, against which all exhibition proposals are judged (I2: 8:55, I2: 29:23). Feasibility studies that have goals that address the priorities are more likely to pass the screening process and given the go-ahead (I2: 8:14). Thus, STE's commission shapes the exhibitions indirectly.

The feasibility study provides goals

In the feasibility study, one of the required components is a goal description (I2: 52:46).

*Goals are a prerequisite for artistic responsibility**

Artistic responsibility entails keeping the exhibition together with respect to content (linguistic/text and shape/form), that is, to have an overall view. In order to have something to orient to and work towards, the project must have goals.

*Goals shape the content of the exhibition**

The foundational principle of the design process in "Once upon a time..." was to work towards an exhibition that meets the goals in the feasibility study. (Whether the exhibition actually *meets* the goals is another matter.)

Artistic responsibility requires a full view and a full view is a prerequisite for control

The artistic responsibility would not be possible to fulfil if the producer had no view (or could not participate) in the activities that develop the content for the exhibition (I1: 20:03, I2: 36:07).

Control is a prerequisite for security

If the producer is able to control the work (if it is about to lose focus or fail to address the goals of the exhibition), this can lead to a sense of security (I2: 36:07).

Control have an effect on the degree of participation

One way for the producer to exercise control over the project is to control the extent to which an external partner participates in the project. In some cases, the producer may terminate the collaboration. This happened in "Once upon a time..." with respect to CID, but it has also happened in other projects (I1: 20:52). It is also possible for the producer to dictate how a member of the project team should work, although there is no indication that this ever happened in "Once upon a time...".

*Control can shape the content of the exhibition**

A logic consequence of the fact that the producer has an artistic responsibility and that such a responsibility requires a full view of the design processes and the possibility to control is that the producer also has the ability to directly shape the content if he/she feels that it fails to "come together". There is no indication in the data that this ever happened in "Once upon a time...".

Relations related to the external partners

The introduction process generates knowledge about work skills

When a potential partner becomes known to the producer, an introduction process can commence. During this process, the producer acquires knowledge about the work skills of the potential partner (I1: 25:53). Obviously, the knowledge may be incorrect or insufficient, a in the case with CID (I1: 28:48).

Knowledge about work skills is a prerequisite for determining suitability

The judgment of whether a potential partner is suitable for the project is based on the knowledge the producer has of that partner's work skills, in combination with the needs that the project may have at the time the introduction process occurs (I1: 25:53, I1: 26:49, I2: 39:01).

Project phase is a prerequisite for determining suitability

The project has different needs in different production phases: it is not certain that a potential partner can contribute throughout the entirety of the project. If there is no need for the work skills represented by a potential partner in the current phase of the project, then that partner can not be invited to participate. The producer must determine the right time for introducing new external partners (I1: 33:06, I1: 37:50, I2: 39:48, I2: 46:38).

Work skill is a prerequisite for suitability

The producer has no need for a partner that "does not fit" the project. A partner is able to participate if he/she has suitable experiences, values, interests, and is open to other people's opinions (I1: 20:03, I2: 22:10).

Work skill is a prerequisite for experience

A consequence of having a suitable work skill for the project is that the partner has experience that they can draw upon when contributing. In other words, the experience and knowledge the partner has gives him/her the ability to determine which types of content that has the potential to meet the project's goals (and how to work to create that content) (I1: 35:09, I1: 57:25, I2: 19:00). Obviously, it is perfectly possible to acquire new experience and knowledge during the project, for example, through meetings with the reference group (I2: 26:15).

Experience shapes the content of the exhibition

Sometimes, the experiences and work skills of a project team member provides ideas for what the content of the exhibition should be. In "Once upon a time...", for example, the scriptwriter worked according to the same approach that he has used in a number of his books for children, which resulted in a "map" of proposed themes for the linguistic content of the exhibition (I1: 53:54).

Experience motivates a work method and work method shapes the reference group meetings

The experience of the persons in the inner creative group does not only motivate an approach towards dealing with the content, it also motivates a ways of working to create the content (I1: 53:54). This experience also shapes the meetings with the reference group and the goals for those meetings (I2: 26:13, I2: 50:06).

Suitability is a prerequisite for security

If an external partner has work skills that are suitable for the project and "represents" what the producer wants the exhibition to be, the producer can feel secure with that person (I1: 20:03).

Relations related to the inner creative group

*Security is a prerequisite for trust and trust is a prerequisite for receiving a role**

These two relations are never mentioned explicitly in the data, but follows logically from the security concept. It is probably very difficult for a producer to delegate a role to a person if he/she does not feel comfortable with that person. Delegation of a role requires trust, that is, the producer has to be certain that the person is able to participate in a useful way.

Receiving a role is a prerequisite for participation

If a partner has no role in the project, that partner can not contribute. This is what happened to CID in "Once upon a time..." (I2: 39:11).

*Participation provides the opportunity to shape the content of the exhibition**

If one is not part of the project team, one obviously has no direct influence over the content of the exhibition. Note: In the case of "Once upon a time...", only persons in the inner creative group had direct influence over the content (I2: 20:43).

*Participation provides the opportunity to shape the design process**

If one is not part of the project team, one obviously has no direct influence over the design process.

The interests of the project team shapes the content of the exhibition

The interests of the persons that are part of the project shapes the content of the exhibition (I1: 36:09).

The knowledge of the project team shapes the content of the exhibition

The knowledge of the persons that are part of the project shapes the content of the exhibition (I2: 47:33).

*The design process shapes the content of the exhibition**

The foundational principle of the design process in "Once upon a time..." was to work towards an exhibition that meets the goals in the feasibility study. Obviously, the way the project team decides to work shapes what the content becomes.

*The content of the exhibition shapes the design process**

The design process appears to be directed towards shaping an image of what the content of the exhibition is to be. Therefore, it is logical to conclude that the image one has of the content at a particular moment partially suggests how to move forward. For example, in "Once upon a time...", the scriptwriter worked according to the same approach that he has used in a number of his books for children, which resulted in a "map" of proposed themes for the linguistic content of the exhibition. The inner creative group then selected a number of these themes and rejected the others (I1: 53:54). It is reasonable to assume that this led to a slightly different work method where the selected concepts were refined and developed.

Relations related to the reference group

Having a notion of what the content of the exhibition is to be is a prerequisite for meeting the reference group

According to the producer, it was necessary to have some sort of idea for the content of the exhibition before the inner creative group could meet the children in the reference group. This idea was influenced by the goals in the feasibility study, but above all by the work of the inner creative group. The idea can be very unclear and vague, but some form of foundation for the discussion was definitely felt to be necessary (I1: 49:58, I2: 1:05:25).

The reference group meetings provide knowledge and material

The reference group meetings have the potential to provide the inner creative group with new knowledge and material. In the case of "Once upon a time...", it could be knowledge about how the children think about storytelling, or whether an idea that the inner creative group has developed "works" or not, or other forms of (physical) material created by the children (I1: 31:44).

Knowledge and material from the reference group meetings shapes the content of the exhibition

The main purpose of the meetings with the reference group is for the inner creative group to be influenced by them, so that they shape the content of the exhibition (I1: 48:53).

Relations related to the recipients

A visit has the potential to be successful

A successful visit entails a number of aspects, including that the recipient should feel motivated, feel that the exhibition concerns him/her, and that the exhibition is emotionally moving (I1: 36:09, I1: 57:25). According to the producer of "Once upon a time...", it was mainly the members of the inner creative group that had the ability to determine how to create a design to meet these criteria (I1: 57:25).

Appendix B – Papers

This appendix contains the six papers that are included in this thesis.

Paper A

Paper A

Taxén, G., Druin, A., Fast C., and Kjellin, M. KidStory: a technology design partnership with children. *Behaviour & Information Technology*, 20(2), 119–125.

BEHAVIOUR & INFORMATION TECHNOLOGY, 2001, VOL. 20, NO. 2, 119–125

KidStory: a technology design partnership with children

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Abstract. We present a new design method that is used within the KidStory project to enable a large number of young children to participate as partners in the design of advanced storytelling technology. The method is an adaptation of the cooperative inquiry method for school environments and uses a combination of evaluation, brainstorming and traditional education methods. These activities have lead to the elaboration of new ideas, impacted the design of existing software and produced a number of interesting new technology designs.

1. Introduction

The KidStory project (http://www.kidstory.org/) is a three-year project funded by the European Union's I3 Experimental School Environments initiative. Its aim is to work with children as design partners to create storytelling technology. One of our research interests is to understand the extent to which this is possible in a school setting, by inviting complete classes of children to participate. We are currently working with the Albany Infant School in Nottingham, UK and with Rågsvedsskolan in Stockholm, Sweden. The focus of this paper is the design methods we use in the Stockholm classrooms. We currently work with two classes: 14 children in one classroom, and 13 children in the other, aged 5 and 7 years when the project started. Their teachers are also active participants in the project. The interdisciplinary research team consists of 7 persons, including computer scientists, educational researchers, user interface professionals and storytellers.

KidStory is now at the end of its second year. The focus of the first year was to refine existing pieces of technology. During the second year, new tangible storytelling technologies were created and the work of the third year will aim to integrate the technologies from the first two years into a creative augmented storytelling space or room.

In the paper that follows we will discuss the design methods we use, examples of resulting technology from these methods, the lessons learned during the first two years of the project, and some directions for future research.

2. Related work

Our design methods with children are derived from *co-operative inquiry* (Alborzi *et al.* 2000, Druin 1999a). This strategy of working with children combines and adapts the low-tech prototyping of participatory design (Schuler and Namioka 1993, Greenbaum and Kyng 1991), observation and note-taking techniques of contextual inquiry (Beyer and Holtzblatt 1998) and the time and resources of technology immersion (Druin *et al.*, 1999). The prerequisites are different, however, since Druin's team in Maryland works in a laboratory setting, with a smaller number of selected children (ages 7 to 11). Our work is also heavily influenced by the *co-operative design* methods originating in Scandinavia (Greenbaum and Kyng 1991, Bjerknes *et al.* 1987, Bødker *et al.* 1987) and the consensus participation of England (Mumford and Henshall 1979), though all of these methods are targeted at adult–adult co-design. Other research groups that have worked with children to improve or

Behaviour & Information Technology
ISSN 0144-929X print/ISSN 1362-3001 online © 2001 Taylor & Francis Ltd
http://www.tandf.co.uk/journals
DOI: 10.1080/0144929001002070 1

Figure 1. Some members of the KidStory design team at work.

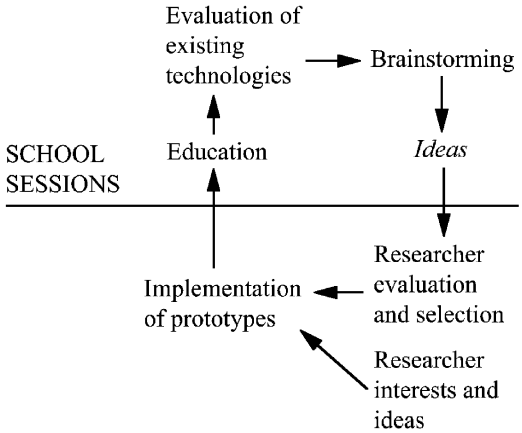

Figure 2. Overview of the KidStory design method. Ideas are generated and refined at brainstorming sessions. A selection of ideas is implemented and the resulting prototypes are brought back to the schools for refinement. Sessions with educational activities and sessions where existing technology is evaluated support the brainstorming phase.

elaborate on technology designs include Scaife and Rogers (1999), Wallace *et al.* (1998) and Smith and Cypher (1999). However, none of these groups involve children continuously throughout the design process.

Figure 1 shows a design session at Rågsvedsskolan.

3. Design method description

The ultimate goal of all our school sessions is to generate new or refine existing technology design ideas. Since our resources are limited in terms of time and in terms of the number of children vs. the number of adults, the design process is about twice as slow as described in Alborzi *et al.* (2000). To achieve the desired goals within the time limits of the project, we have sometimes found it necessary to use 'off-line elaboration', where adults and children elaborate on ideas away from the school sessions. We have also chosen to focus on creating an environment that will generate a large quantity of ideas rather than to analyse group dynamics and/or the capabilities of individual children to adapt the sessions to generate complete design specifications. Thus, the role of the adult researchers is, apart from taking an active part in the school sessions, to evaluate the ideas that are generated, see how they relate to the larger goals of the project, select a number of them for implementation and possibly elaborate on them.

In general terms, our design process, which is illustrated in figure 2, proceeds as follows: Sessions with a more traditional educational set-up are combined with sessions that evaluate existing technology. Together, they provide the children with a framework for thinking critically about technology and also help children and adults to learn how to become design partners. The result is design suggestions that can either be used directly to make changes to existing pieces of technology or be fed into brainstorming sessions where ideas for new technology are generated and/or elaborated upon. The ideas that are generated are analysed by the adult researchers and a number of them are selected for implementation. Both researcher interests and constraints on time and technology influence the selection process. Sometimes, the adults and/or children will elaborate on the ideas 'off-line' to save time. Prototypes that implement the ideas are then built and brought back to the school for further refinement.

Thus, there are three main types of session activities: *educational* (which in this context is assumed to mean sessions whose goal is to improve the children's knowledge of a particular role or concept that is related to the KidStory project), *evaluation* (generating suggestions for improvement of existing technologies) and *brainstorming* (idea generation). Sometimes, more than one set of activities occur at one session. Each session is normally held once for each age group, with small or no modifications between age groups. A typical session is about 60 minutes long and often starts with a short briefing for the whole group (5 – 15 minutes), after which children and adults split up into smaller mixed teams of 2 – 3 adults and 3 – 6 children. After the teams have worked for about 30 – 45 minutes, they gather for a short debriefing (5 – 10 minutes). Each child has been given a KidStory project journal in which ideas and design suggestions are recorded. The debriefing typically includes writing/drawing in the journals. Often, adults will ask the children to describe what it is that they have recorded so that no information is lost. The descriptions are then typed and put in the journal next to the appropriate drawing or text. When technology is being evaluated, the adults also make contextual inquiry notes that include what is being said and actions that are taken by the children. This information is then analysed and fed back into the design loop. Throughout the first two years of the KidStory project, we have held 38 sessions. 16 sessions had educational activities, 22 had evaluation activities and 9 involved brainstorming.

3.1. *Sessions with educational activities*

Educational sessions are held mainly to help the children to become familiar with the role of design partner. In addition, these sessions also help when a better understanding of a concept or role is needed before brainstorming or evaluation activities can take place. Our five-year-olds, for example, had trouble grasping the concepts of criticism and brainstorming. Therefore, a number of sessions were held where we talked about being inventors, a role we felt captured the spirit of the work being done within project. We also talked about problem solving with a focus on identifying problems with existing objects such as milk cartons and computer mice. A typical education session proceeds as follows:

Children and adults gathered on the floor and talked about what it means to be an inventor and the children were asked to describe what inventors do. The group also talked about the KidStory project and that the adults would like the children's help with inventing new storytelling tools. The children were then asked to be inventors for the first time in KidStory. We asked them to work individually to invent a new kind of sandwich and to build a low-tech prototype of it using such materials as paper, clay, glue and crayons. Afterwards, the children were asked to describe their sandwiches and the adults helped them write down the descriptions in their project journals. A photograph of each sandwich was later added next to its corresponding description in the journals.

3.2. *Evaluation sessions*

Evaluation sessions are held to obtain information that can be used to improve existing technology. These sessions have focused both on technology that we have built within the project and on commercial applications. The aim is enable children to improve their abilities to identify problems with existing technologies and to encourage them to use constructive criticism during the evaluation. This kind of session is particularly powerful when suggestions made by children and adults are implemented and brought back to the school, since it can give children a feeling of empowerment and ownership of the technology (Druin 1999b). A typical evaluation session proceeds as follows:

The children and adults gathered on the floor and the children were asked to work in pairs to figure out what was good and bad about KidPad (one of the storytelling technologies that have been developed by the KidStory project). While the children were working, the adults took contextual inquiry notes and also wrote down their general impressions and thoughts. Afterwards, the children were asked to write or draw what they liked and didn't like about the program in their journals. The session identified a number of problems that later influenced the general design of KidPad (see section 4).

3.3. *Brainstorming sessions*

Brainstorming sessions are held to produce ideas for new technology and elaborate on existing ideas. The aim is to create a setting where it is felt that any idea (that is related to the task at hand) is welcome. We have found that our particular group of children is very comfortable with the low-tech prototyping method, (e.g., to build non-functional prototypes with cardboard, crayons, balloons, etc.). A typical brainstorming session proceeds as follows:

The children and adults gathered on the floor and the session leader started by reviewing the role of inventorship and also talked a bit about what a storytelling machine could be like. In the younger age group, the leader also reviewed previous inventing sessions. The children and adults talked about different machines for telling stories and some ideas were written down on a blackboard. After this, the children and adults split up into mixed teams of 2–3 adults and 3–4 children. Each team used low-tech prototyping materials to build models of their machine. The children were then asked to draw interesting details or examples from their machines in their project journals. Finally, everybody gathered on the floor and each team described their machine to the others.

3.4. *Evolution of the design methods*

We have found that our session content has changed substantially during the first two years of the KidStory project. The focus of the first year was to establish a design partnership between children and adults and to refine two existing pieces of desktop computer software, KidPad and Klump. Therefore, the main part of the sessions had education activities, such as story creation in pairs, and evaluation activities, such as traditional contextual inquiry. The number of brainstorming sessions has gradually increased during the second year, in part because the focus of the project has shifted towards creating completely new storytelling technology. We also believe that this is because the design partnership between adults and children has become stronger. In year two, 33% percent of the sessions had educational activities, a 20% decrease with respect to year one. 62% of the sessions had evaluation activities, an increase of 9%. 42% of the sessions involved brainstorming, an increase of 36%.

4. Results

This section presents some results that our design methods have produced. During the first year of the KidStory project, a total of 510 design suggestions for the KidPad and Klump software programs were obtained from the Swedish and UK schools. 288 of the design suggestions were from contextual inquiry notes and 222 from the children's journals. The suggestions were divided into a number of different categories that were used in the technology implementation process to improve the programs. What follows in the sections below are descriptions of the technology that resulted from of our design methods:

4.1. *First year technologies*

KidPad is a freely available collaborative drawing and storytelling tool (http://www.kidpad.org/, Benford *et al.* 2000). Co-present users can draw together on a zoomable drawing canvas using one computer mouse each, and image elements can be connected by hyperlinks. Finished stories can be saved as HTML (or in a special KidPad file format) for sharing with other people.

When KidPad became available for use within KidStory, its basic functionality was similar to when it made its original appearance (Bederson *et al.*, 1996), and a number of technology evaluation sessions were held to obtain suggestions for improvement. Some issues were identified immediately by adults and children (such as the fact that the children were fighting over the single computer mouse and that the save/load screen had text icons in English) and some became apparent after the children had become more familiar with the program. For example, some of the original tool images were ambiguous, so the children were asked to provide their own tool images. Another example is a fill tool that was requested repeatedly by the children, since it takes a lot of time to fill large areas by using crayons alone. In total, 64% of the suggestions from the contextual inquiry notes and 33% of the suggestions from the children's journals were implemented.

The Klump is an application for conjuring up stories and collaboratively developing creative ideas. It is a 3D graphical object with colourful abstract textures and a physically-based spring model that gives it organic dynamic properties. It also generates sounds that are directly related to its movements and the user interaction. A number of evaluation sessions were held to improve the user interface of the Klump. Some issues that were identified included the fact that the Klump went back to its original shape after a while and that there was no way rotate the shape. In total, 75% of the design suggestions for the Klump were implemented.

4.2. *Second year technologies*

During the second year of the KidStory project, tools that went beyond the desktop for storytelling were developed. These technologies come out of a rich history of tangible user interfaces (Harrison *et al.* 1998, Ishii and Ullmer 1997, Fitzmaurice *et al.* 1995), ubiquitous computing (Weisner 1991) and augmented environments (Wellner *et al.* 1993). With recent developments in radio frequency identification (RFID) tagging, more low-cost flexible and unobtrusive physical interfaces can be constructed (Want *et al.* 1999). Some of our technologies take advantage of these developments.

A number of brainstorming sessions was held to generate ideas for new designs that build on this work. Children and adults were asked to build low-tech prototypes of 'storytelling machines' together, machines that could be used as tools for authoring and re-telling of stories. This generated a number of interesting ideas and some of them were chosen for implementation. The resulting prototypes were brought back to the school for further refinement. These include the *Story Die*, the *Story Sofa* and the *Story Feet*.

The original idea for the Story Die was that the sides of a large die would hold different stories. When you placed the die into a special 'Story Owl', as shown in figure 3, the owl would read the story associated with the topside of the dice to you. The current implementation of the Story Die is a cardboard box with one hidden RFID tag attached to each side. This allows users to associate multimedia content with each side of the die. Initially, the die was used to store sounds, but it quickly became obvious that some children needed other kinds

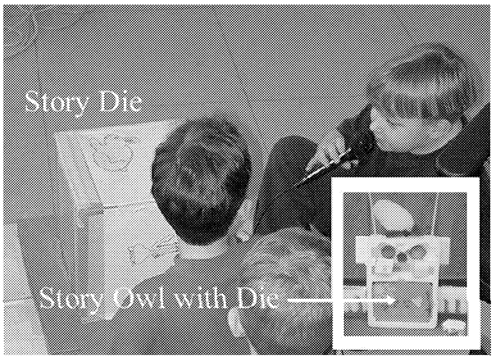

Figure 3. The Story Die and Story Owl. A sound can be associated with each sides of the die. The sounds can be played by placing the die inside a special Story Owl.

of multimedia, such as KidPad images, to be associated with the die. An implementation of such a die was used at a KidStory exhibition in an improvised performance of 'A Day in the Desert'. The children threw the die to select random scenes (e.g., images and sounds) that they had created, such as 'We Meet Dangerous Creatures' and 'We See a Mirage'.

The general functionality of the Story Sofa and the Story Feet are similar. They originate from ideas that appeared independently in both age groups. The idea is that when you sit on the sofa or stand on a pair of feet, you are transported to a different location or a story world. When three users sit on the three seats of the sofa in different combinations, different scenes (with images and sounds) appear. When a user step onto a pair of feet, the associated scene is retrieved.

5. Lessons learned

During the first and second year of the KidStory project, we have encountered a number of challenges. These can be divided into two main categories: challenges related to the design partnership between children and adults and challenges related to our design method.

5.1. *Challenges of children as design partners*

When working with children as design partners, it is necessary to negotiate a power structure between children and adults so that neither children nor adults are completely in charge of the technology design. As reported in Alborzi *et al*. (2000), this can be difficult and time-consuming. We have found that this can be even more difficult to achieve in a school environment where time is short and a power structure already exists between children and teachers. Our children were not used to providing critical feedback on designs and some of them were not comfortable with working directly with adults. Also, few of the adult researchers had previous experience with working with children. To overcome these challenges, a researcher from Stockholm spent three months working with Druin's group at the University of Maryland. Even with this transfer of methods, the child–adult partnership in Sweden took about 12 months to establish. We have also gradually learned how to address the children. It is important that tasks are presented in a concrete and precise but still open-ended way. It's also crucial that enough adults are present at each session, more than three children per adult can be very problematic.

5.2. *Challenges of our design method*

Sometimes, the general goals of the project will be in conflict with the children's goals. For example, during the first few storytelling machine brainstorming sessions, the children were providing many ideas for machines that 'tell you stories from around the world'. Although such a machine would certainly be interesting, the researchers felt that it was important that some kind of authoring functionality is present in all KidStory tools. Therefore, an education session was held to try to introduce the concept of authoring and some of the basic elements of narrative ('who, what, where') to the children. Even though this session was successful, it was felt that additional similar sessions could be helpful. How many such sessions to use in situations like this is still an open issue, since an increased amount of education sessions means that there are fewer opportunities left for brainstorming.

Our project goals are the same for both child age groups. At the beginning of the project, this was problematic since concepts such as design, invention and authorship are hard to grasp for children at the age of five. However, because they became exposed to the project at an earlier age than the other age group, it is possible that the younger children will be in a better position to think critically about technology features towards the end of the project.

Whenever we revert to 'off-line' elaboration, there is always a risk that we interpret the session ideas incorrectly. Also, design concepts may change when they are adapted for implementation and the evolution of a prototype may be substantially different between two sessions, which can be confusing for the children. It is not certain that implementations chosen by adults are interesting to all children, so an important question is whether to involve the children more in the selection process (by, for example, voting on ideas). Because of our limited resources, we have chosen not to do so, but we are examining different ways of increasing the children's influence when it comes to selecting designs for implementation.

6. Future work

Although designing with children is often extremely rewarding, it takes plenty of patience and time. During the third year of KidStory, our goal is to integrate our current storytelling technologies into a room-sized interactive environment where children can author and experience stories. This will require a design effort that is larger than what we have attempted during the first two years. Since the resources available in the school are the same, it has been difficult to decide whether to focus on refining the design method itself to make it more efficient or on accelerating the technology design by increasing the amount of 'off-line' idea elaboration. One way to address the challenge could be to select a small number of children and continue to work with them as design partners, and at the same time let the rest of the group inform the design process through evaluation sessions.

Acknowledgements

We are deeply grateful to our design partners: children and teachers at Rågsvedsskolan and at Albany Infant School.

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Paper B

Paper B

Taxén, G. Introducing Participatory Design in Museums. In *Proceedings of the 8th Biennal Participatory Design Conference (PDC 2004)*, 204–213.

Introducing Participatory Design in Museums

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ABSTRACT

This paper describes how a set of participatory design methodologies have been introduced to and adopted for museum exhibition design. It provides a brief historical account of museums and reviews some current trends in museum exhibition design. Furthermore, the paper outlines a number of reasons why participatory methods may be appropriate for museums, and two such methods are described: one for evaluation of exhibits, and one for exhibition concept development. Evaluation of the methodologies suggests that they are efficient; both in terms of resources and in the richness of the data they produce. In addition, it appears that they are capable of both supporting and extending established museum design practices.

Keywords

Museums, Participatory Design, Evaluation, Concept Development

1. INTRODUCTION

Most participatory design (PD) projects are rooted in a desire for change, often with respect to the way a workplace organisation functions or in the way users are being involved in the design of new technology artefacts. A majority of the early cooperative projects in Scandinavia had a political agenda in the sense that their aim was to empower workers to shape and influence the introduction of new technology into their work environment [15]. The project described in this paper has a family resemblance with these early projects in the sense that it actively seeks to empower museum visitors to influence the design of the exhibitions they visit, to a larger extent than what is common practice today. However, as we shall see, our approach is somewhat less confrontational.

The fact that participatory design is able to produce high-quality user-oriented information technology does not necessarily mean that it is straightforward to introduce such methods into other domains. In our case, we have found that there is a need for continuous evaluation of our methods, not only to "validate" the products of the design process with respect to the established design practice (i.e., that our participatory methods actually contribute to the museum design process in general), but also with respect to how the different stakeholders involved regard their participation.

The next section briefly describes the museum context and how design work is typically done in museums today. It also draws out a number of similarities between the circumstances that led to the development of cooperative design in the 1970s and current trends in museum exhibition design. Section three introduces our project and describes its most prominent influences. Section four contains an overview of the first main achievement of the project: a participatory evaluation methodology for museum exhibitions. Section five constitutes the main part of the paper and describes, in some detail, how we have worked with visitors to develop concepts for a new exhibition at the Vasa Museum in Stockholm. This section also presents an analysis of the concepts, and shows how they can be related to trends within current museum research. Section six presents an evaluation of our work method and section seven contains some directions for future research.

2. MUSEUMS

In the mid-15th century, Italian nobles begun to arrange acquired artworks from ancient Greece and Rome with the specific intention of exhibiting them to invited guests holding important social positions. As a result, a new general interest in these cultures was raised, and a few hundred years later, private collections of items from around the world were abundant in Europe. The way of displaying them gradually changed, however: the function of the collections developed from being tools for forwarding the owner's social position to exhibitions of an encyclopaedic nature. Some collections were kept for teaching purposes by individual researchers at universities, but many were put together to represent the owners' view of the world. A classic example of these kinds of displays is the *Wunderkammer*, the "cabinets of curiosities".

During the mid-17th century, the Royal Society was formed in England. One of its aims was to develop a shared language among tradesmen, scientists and the church. To support this process, the Society assembled a collection of items, known as its Repository, to physically represent the language. By arranging for an institution to own the collection rather than a private individual, it was hoped that it would stand a better chance of surviving and growing than private collections, which tended to disperse at the death of the owner. The Royal Society also appointed a *curator* to manage the laboratory that was made available in connection with the Repository. At this time, the collection was not accessible to

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the public; it was only available to members of the Society. Today, the Repository is a part of the British Museum.

After the French revolution, the collections of the aristocracy were appropriated in the name of the new Republic, gathered together, reorganized and transformed. The aim was to make the collections available to all citizens of the Republic. Another reason for organizing this new type of museum was to display the decadence and forms of control of the old regime and to represent the democratic values of the new. Thus, the nature of the content changed from that of a three-dimensional encyclopaedia to less specific, changeable information. A similar perspective was gradually adopted throughout the rest of Europe.

The evolution of the modernist philosophy in the nineteenth century influenced the transformation of museum collections into representations of chronology so that the exhibitions evolved into a physical record of the past. This is a practice that remains today, but many other presentation and grouping techniques are also used in contemporary museums. More detailed descriptions of the history of museums can be found in, e.g., [4][24].

Thus, most modern museums are concerned with collecting, preserving, and providing access to important cultural and historical artefacts, with the explicit intention of educating and informing the general public about those artefacts. The curator role remains extremely important. Curators often plan and oversee the arrangement, cataloguing, and exhibition of the museum's collections and, along with technicians and conservators, maintain the collections. They are frequently expected to coordinate educational and public outreach programs, such as tours, workshops, lectures, and classes, and may work with the boards of institutions to administer plans and policies. Additionally, they may research topics or items relevant to their collections [29].

2.1 Museum Exhibition Design

Historically, the curator often single-handedly designed exhibitions. Today, most museum design teams also include educators, designers, artists, carpenters, technicians and maintenance staff. New exhibition projects typically begin with a *conceptual phase* in which a subject and a visitor target group are selected. It is common to make use of a *front-end analysis* to generate subject candidates [10]. In such an analysis, previous projects are assessed and demographic data of the visitor population is acquired. It is also common to assess the kinds of knowledge the target group have of the chosen subject, their interests and priorities, or to attempt to find ways to attract visitors from community groups that seldom visit museums (e.g., [14], [17], pp. 179-181). After the production team has generated a number of ideas, available resources for completing the project are assessed, together with the appropriation of a suitable time slot in the exhibition schedule.

A *development phase* follows in which funding is acquired and the physical and educational design of the exhibition is completed. After a project budget and an exhibition plan have been completed, production can commence. Activities include building, preparing, mounting and installing the exhibits, and also involve training of the educational staff and marketing. Since it is costly to redesign exhibits after they have been put on display, many museums have adopted a prototype-oriented design process where mock-ups or early exhibit versions are tested by selected groups of visitors ([10], pp. 39-43). Such evaluations of prototypes are often referred to as *formative evaluation*, and can be directed at both physical and educational aspects of the exhibits.

The time period when the exhibition is on display is often referred to as the *functional phase*. In this phase, educational programmes are implemented and the exhibition is typically also presented to the public through pre-scheduled guided tours. It also includes personnel administration and maintenance work, and ends with the dismantling of the exhibition and the balancing of accounts. In this phase, *summative evaluation* is used to determine if the exhibition met its goals. Such evaluation is often relatively easy to conduct, but may lead to expensive re-design of entire exhibits.

The production cycle ends with an *assessment phase* where the exhibition development process is evaluated. The intended outcome is a number of suggested improvements to the production process and ideas for future exhibitions. A large number of evaluation methodologies exist, including questionnaire surveys, in-depth interviews, structured and semi-structured interviews and behavioural observation [5]. Often, several of these evaluation methodologies are combined to triangulate the findings and strengthen the conclusions of the data analysis.

2.2 A New Arena for PD?

The main principles of museum exhibition evaluation originated in seminal work by Robert Miles' group at the Natural History Museum in Britain in the 1970s [26]. A gradual increase in interest in evaluation has led to the formation of the *museum visitor studies* research field, which builds on theory from sociology, psychology, education, marketing, management and leisure studies. It covers subjects such as demographics, data on attendance, psychological profiling, patterns of visitor behaviour, and the development of educational assessment methodologies. During the last decade, a growing number of authors within visitor studies have argued for a focus shift in exhibition production from curators and subject specialists towards educators and evaluators (e.g., [34][25][22]). As a result, evaluation, front-end analysis and formative evaluation are becoming increasingly more important in museum exhibition design.

Thus, visitors or visitor representatives contribute to the design of exhibitions in different phases of the exhibition design cycle, but they are rarely invited to become part of the design team itself. In the terminology of Druin and Fast [13], visitors today are asked to assume the roles of user, tester or informant, but they are very seldom invited to become design partners. The reasons are probably largely historical. Traditionally, the main tasks of most museums have been to maintain a number of collections and to make those collections available to the public. This means that the curator and/or the museum staff must have expert knowledge about the museum's different artefacts. In the 1970s and 1980s, most museums became heavily influenced by communication theory, which led to exhibition design approaches where content was "encoded" by these experts into the exhibition and subsequently "received" by visitors [25]. The visitor studies field largely arose from the need of determining whether this "encoding" was successful or not. Visitor "representation" has increased through the inclusion of educators, evaluators and designers in most exhibition design teams, but the fact that visitors have expert knowledge too – they know what it means to be a visitor – is still not acknowledged enough to allow them to take an active part in exhibition design.

In many ways, this situation resembles the situation in the information system industry that led to the formation of cooperative and participatory design. The focus on usage models, psychological profiling and human factors within human-computer interaction in the 1970s and 1980s (c.f., [3]) appears to be common within visitor studies research today. Another similarity is that museums are subject to a strong extrinsic pressure for change, just as the Unions in Scandinavia constituted a pressure for change in the way technology was being designed for the workplace in the 1970s and 1980s [15]. Today, most museums face increasingly fierce competition from other entertainment providers, such as theme parks and similar attractions. Multimedia-capable computers with high-bandwidth Internet connections are becoming ubiquitous in Western homes and schools, providing a readily accessible and extremely rich source of information. At the same time, the attendance figures for many museums are decreasing at the same time as their governmental financial support is gradually being withdrawn. Thus, many museums are seeking more visitor-focused ways of approaching (and extending) their audiences, a reorientation that requires a more substantial visitor-designer dialogue than the field of visitor studies currently seems to be able to provide.

Thus, it would seem that museums might benefit from the introduction of participatory design methodologies. However, there appears to be very few documented research projects where such approaches have been implemented and evaluated. At the time of writing, we have only been able to identify one example: the HIPS project [6], where the aim was to allow people to navigate both a physical space (e.g., a museum) and a related information space at the same time (e.g., information about the items in the museum). The project initiated a number of workshops where visitors and museum staff worked together to design the user interface of a portable appliance that would allow visitors to acquire information about a museum artefact or a piece of artwork. The participants included a museum director, an art expert, a museum custodian, a fine arts superintendent, the administrator of a museum bookstore and two tourists. While these workshops provided a number of very useful ideas for technology design and implementation, they did not focus explicitly on exhibition design [7].

3. PARTICIPATORY DESIGN IN MUSEUMS

The goal of the project described in this paper is to strengthen visitors as stakeholders in technology-oriented museum exhibition design through the use of participatory design methods. The methodologies we use are developed in collaboration with museum production teams to support current museum design practices. Thus, the project is not only about technology development, but just as much about methodology adaptation: modifying and appropriating design methods from the human-computer interaction field to support and strengthen another, previously established, design practice. It is this latter aspect that will be of concern in this paper. See [38] for an overview of some of the technological aspects of the project.

The project is now approaching the end of its second year. A large amount of this time has been devoted to establishing different partnership roles and securing the commitment of the different participants (c.f. [9]), work that is embodied in a long-term installation that we developed for one of our partner museums [37]. Our approach is to gradually introduce participatory methods where they are deemed appropriate by both the partner museums and the project researchers. In order to ascertain that the outcome of the project is useful from a museum perspective, each method introduced is also evaluated and validated through different means.

Currently, we are working with the Museum of Science and Technology (www.tekniskamuseet.se) and the Vasa Museum (www.vasamuseet.se) in Stockholm. We also collaborate with Swedish Travelling Exhibitions (www.riksutstallningar.se).

3.1 Project Influences

Our project builds upon the work of a number of previous cooperative and participatory projects. The main influences are the "tools perspective" from UTOPIA [16], the future workshop [27], and the KidStory variation of Cooperative Inquiry [36][12].

The KidStory project worked with school children (ages 5-9) and teachers to design new storytelling technologies. The design cycle consisted of three main types of session activities (figure 1): educational (assisting the children in acquiring knowledge of a particular role or concept related to the project), evaluation (generating suggestions for improvement of existing technologies) and brainstorming (exploring ideas and possibilities without having to make a commitment to act upon them).

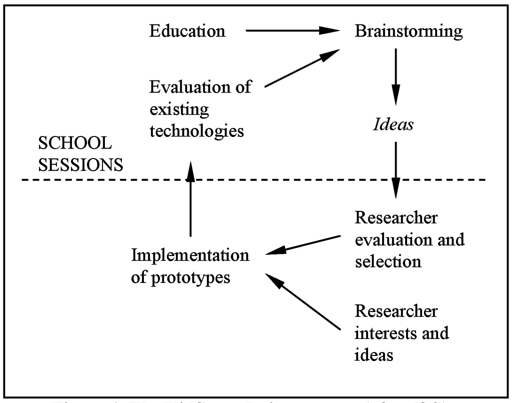

Figure 1. The KidStory design process (after [36]).

The education and evaluation sessions provided the children with a framework for thinking critically about technology and also helped them to develop a shared design vocabulary. The outcome of these sessions was typically a number of design suggestions that were either used to make changes to existing pieces of technology or were fed into brainstorming sessions where ideas for new technology were generated and elaborated upon. The researchers then analysed the subsequent ideas and selected a number of them for implementation. Both researcher interests and constraints on time and technology influenced the selection process. Prototypes that implemented the ideas were then built and brought back to the children's school for further refinement.

Although they were not thought of as such at the time they were developed, a number of the KidStory prototypes can be seen as interactive exhibits and/or installations. Examples include a "story owl" that would tell you stories from around the world, a "magic sofa" that would transport its users to exciting places, a "magic carpet" that allowed a number of users to collaboratively navigate a virtual environment, and a "technology fair" where a number of the prototypes were integrated and exhibited to the children's parents and relatives. This, in conjunction with fact that the design methodology worked very well with such young participants, made it appropriate as a candidate for adoption to the museum domain. However, the first task of our museum project was to develop a participatory methodology for museum exhibition evaluation.

4. PARTICIPATORY EXHIBITION EVALUATION

The Museum of Science and Technology is currently planning a redesign of its Science Centre gallery. To support the process, the museum has initiated a number of evaluation activities, including assessment of the current exhibits and observations of other Science Centre galleries in Europe and the United States. However, much of this data is based on behavioural observation and the data seemed to lack detailed feedback from visitors. Because the museum's resources are limited, interviewing a larger number of visitors was not an option. Since the evaluation methodologies used by the KidStory project had been shown to be both efficient and provide a large number of design suggestions (apart from generating feedback), we decided to attempt to adopt one of them for the museum. One of the temporary installations in the Science Centre gallery was selected as the target of the evaluation. The method we appropriated is a variation of the future workshop [27]. It also shares some features of the grounded theory method [20] and the Post-Its-based evaluation activity described by Allison Druin in [12].

We hosted three two-hour workshops at the museum, two with target group representatives (school classes), and one that was open to the public. We began each workshop by encouraging all participants to interact with the installation while the facilitator gave a brief talk outlining the installation's implementation and main goals. When every participant had been given a chance to familiarise themselves with the exhibit, we moved to a quiet conference room in an adjoining part of the museum. Here, the facilitator briefly described the workshop goals and its different stages. Then, the participants were given green and red Post-It notes and were asked to write down at least three positive aspects of the installation on the green notes (one statement per note) and at least three negative aspects on the red notes, and put them on a random location on a whiteboard. When all Post-It notes were positioned on the whiteboard the facilitator asked the participants to collectively attempt to group similar notes together and summarise their content in a heading. When all notes had been accounted for, we took a short break after which the participants were asked to form groups of about five persons each. The groups were encouraged to examine the whiteboard and try to think of ways in which the negative aspects of the installation could be improved while preserving the positive aspects. Each group was shown to a quiet, private area and were given about half an hour for discussions. When the groups had reconvened in the conference room, we spent another thirty minutes talking about what the groups had discussed and what design suggestions they had thought of. Each workshop was documented by two note-takers.

In order to attempt to assess whether our new method also produced data that correlated to standard summative evaluation methods, we triangulated the workshop data with data from observations and interviews. The results suggest that the participatory evaluation method brought forward the same general themes (both positive and negative) as the summative evaluation, as well as generating a large number of ideas for improvement. For further details, see [37].

5. PARTICIPATORY EXHIBITION CONCEPT DEVELOPMENT

During the autumn of 2000, a number of sulphate deposits were discovered on the surface of the world-famous Vasa vessel [11]. Vasa is a Swedish 17th-century warship that sunk just a few minutes into her maiden voyage. The ship was rediscovered and salvaged in 1961 and was preserved through a 26-year conservation process. Unfortunately, the wood contains a large amount of sulphur (assimilated from the water when the ship was resting on the sea bottom), which has gradually reacted with oxygen to form sulphuric acid. The acid and its deposits threaten to destroy the ship if nothing is done to terminate the process. Today, the reasons behind the problem are well understood, but a satisfactory solution does not yet exist. Therefore, five different chemistry and conservation research teams have been engaged. The Vasa Museum has very recently initiated work on a new large-scale exhibition that will describe the sulphuric acid problem to the public and present the outcome of the chemical research on a continuous basis. Because the visitors to the museum constitute an extremely heterogeneous group (the Vasa Museum is one of the largest tourist attractions in Sweden), and the exhibition will feature modern technology, the issue of usability became important. Thus, our museum project at the Centre for User Oriented IT Design (CID) was engaged to assist in the exhibition development process.

It soon became clear that a reasonable start for the usability work would be to focus on the part of the exhibition that will describe the sulphuric acid problem. The Vasa Museum had already established a number of educational activities where the problem was brought up and discussed, e.g., during their guided tours, through a small temporary exhibition, and through high school teaching activities.

This meant that through the teaching programme, the museum had already established direct contact with different groups of visitors when CID was approached (adolescents is one of the target age groups of the sulphuric acid exhibition), and that these visitors already had some knowledge of the problems the new exhibition is intended to illustrate. Consequently, by working with these students, the educational activities that were initiated at different occasions in the KidStory project were not immediately necessary.

Thus, the museum re-engaged the ten most recent high school student visitors that had worked with the sulphuric acid problem. Together with three members of the museum's educational staff, these students participated in four different two-hour workshop activities between December 2003 and January 2004 to develop concept sketches and ideas for the new exhibition. The overarching goal of the sessions was to assist the students in formulating the aspects of the background material that they thought was most important, and to gain insight into how they, as museum visitors, would like to encounter those aspects in an exhibition.

The goal of the first session was to allow the visitors to formulate a set of criteria for "good" and "bad" exhibitions. The session discussed exhibitions in general and what visitors feel to be efficient, educational and fun. The first session also included an evaluation of the museum's existing exhibitions to see whether they incorporated the criteria or not.

The second session initiated an exhibition concept development process. The goal was to generate ideas for concepts that embodied the positive criteria from session one, while avoiding the negative criteria. At the end of the session, the participants evaluated the concepts. This evaluation was the foundation of a selection process, where CID researchers identified a number of interesting aspects for the participants to refine during session three.

The third session refined and concluded the concept development work, and the outcome was documented (by the participants themselves) in the form of scenario videos. The session ended with a general discussion about the videos.

The last session was devoted to feedback. Researchers from CID and museum personnel gave an account of how the students' work had been analysed, what the results of the analysis were, and how the museum intended to use the results. The session ended with an evaluation of the work method itself.

Because sound and video recording was deemed impractical, we decided to document all sessions through observational notes and digital camera images.

5.1 Session 1

The first session was hosted by the Vasa Museum. After a brief introduction, the session facilitator distributed a number of Post-It notes – red and green – and encouraged the students to think of the best exhibition they had ever visited, and to write *why* it was good on green notes. Correspondingly, the students were asked to think of the worst exhibition they had ever visited and note why it was bad on the red notes. As they finished writing the notes, the students positioned them on a blackboard at random locations. The facilitator then encouraged the students to work together to group the notes on the blackboard, so that aspects that belonged together were positioned close to one another, and to formulate a suitable heading for each group of notes. The headings for positive aspects were: "guides", "visual images", "physical environment", "sound", "do yourself (experiments)", "models" and "other issues". The headings for negative aspects were: "guides", "balance between play and fact", "physical environment", "too much text" and "other issues".

After this, the students were asked to copy the headings to paper and read through all notes on the blackboard. The students were then divided into three groups (about 3-4 persons in each group) and were asked to find examples of the aspects mentioned in the notes in the Vasa museum. After about one hour, the groups reconvened to discuss the results.

The discussion indicated that the students thought that the design of the museum's exhibitions had been largely successful. Models (large and small), the design of the environment, and informative multimedia presentations gave an impression of "how it felt" to live with and on the Vasa. However, the lighting level was thought to be too low in general (this is a requirement of the conservation process), and this, in combination with poor placement of text labels made many of the exhibitions difficult to understand.

The discussion also raised a number of more general issues that the students considered important for museum exhibition design, including:

> One should strive to provide a feeling of authenticity, to transport the visitor to a different place, environment or age. It is important to use authentic artefacts and create a sense of quality in the physical design of the exhibition environment.
>
> Visitors want to be able to come close to artefacts, without restrictions, and it is important to be able to see artefacts from all directions.
>
> It is important that the goal and context of the exhibition is immediately obvious to the visitors.
>
> Language aspects are important in a museum like the Vasa museum. Should all texts be in English as well as Swedish? Should other languages be included? How much text should there be?
>
> The exhibition must be accessible to everyone.
>
> The exhibition should have a certain tempo in its presentation – not only in image and text, but also in the way visitors are guided through the gallery.
>
> Points of view: most visitors want to be able to see through artefacts, see inside, or see artefacts from the inside, etc.

As we shall see, many of these discussion topics, as well as aspects from the Post-It notes, are embodied in the concepts the groups began to develop in session two. Thus, the first session both provided the students with a number of "basic requirements" to work from, as well as providing evaluation data on the museum's existing exhibitions. Furthermore, members of the museum staff have corroborated the evaluation data to a large extent: most of the issues mentioned by the students had been raised by the museum's different summative evaluations. However, our workshop method required far less resources.

5.2 Session 2

The second session was hosted by CID at the Royal Institute of Technology. The same student participants as in session one were present, together with three members of the Vasa museum's educational staff (two of these persons were present but did not actively participate in the first session). The groups (same as session one, with the addition of one museum educator each) were asked to work together to develop exhibition concepts, without presupposition with respect to available technology, funding, and the physical environment. This phase of the workshop took about one hour. The groups used low-tech material to illustrate their concepts: coloured paper, pens and pencils, scissors, glue, tape, marbles, newspaper and magazine clippings, clay, LEGO bricks, etc.

After a 10-minute coffee break, the groups continued to work for about 25 minutes. The facilitator then asked the groups to present their concepts, in their current state, to the rest of the participants. During these presentations, the participants also evaluated the concepts: each participant was asked to write (anonymously) three positive aspects and three negative aspects of the concepts (excluding their own) on different pieces of paper. The facilitator collected the papers at the end of the session.

5.2.1 Concepts: Group 1
The first group chose to organise their work around a paper sketch. The exhibition was conceived of as a collection of individual interactive exhibits, situated close to the real Vasa vessel. The concept included the following features:

A projection onto the real ship that illustrated the negative effects of the sulphuric acid problem. The rationale for this projection was to generate a general interest in the rest of the exhibition.

Access to paper-based information in several languages that visitors could take with them.

Touch screens where visitors could search a database.

Several short films in connection with the exhibits that illustrate how the chemical process proceeds. The process would be visualized in different ways, to better match a large range of target groups.

A large number of robots that could follow visitors around the exhibit, to answer questions (in many languages). The robots would remember what people asked it, and make use of cameras and microphones. The robots were not guides, but "helpers".

A poster with text for older visitors. Models and texts for younger visitors.

An "experiment station" where visitors could attempt to reverse the sulphuric acid process in a piece of wood.

5.2.2 Concepts: Group 2
The second group had positioned a large glass dome at the centre of their exhibition design (figure 3). Inside the dome was an animated 3D hologram. This non-interactive animation begun by showing the entire Vasa ship and then zoomed into the wood, peeling off layer after layer, illustrating the sulphuric acid development process. The holographic "camera" also moved around the ship interior (which is inaccessible to visitors for security reasons). A suitable text would rotate around the bottom edge of the dome, and would also be read by a speaker voice.

The group had positioned a number of smaller domes around the large hologram where visitors would be able to, through interactive virtual experiments, discover how the sulphuric acid is to be removed from the ship. These displays were also holographic, so that the content was visible from all angles (although only one person at a time would be in control). Each dome would illustrate a separate concept (the chemistry of the preservation process, the physics of the supporting scaffolding of the ship, etc.). A number of encouraging questions would also appear on the domes.

Figure 3. A glass "dome" containing Vasa as a 3D hologram. The small "domes" are interactive exhibits where further information can be found.

5.2.3 Concepts: Group 3
The third group worked with a concept that involved models and mechanics to a large extent. Their exhibition consisted of a large, long wall containing a moving model (figure 4). The model was designed as a timeline where time flows from left to right. A physical icon representing the Vasa ship would move along the wall, illustrating how the ship was launched, how it sank, how waste in the water would provide the sulphur, etc., until the ship was salvaged and brought into the Vasa Museum at the far right. There were also a number of "binoculars" set into the wall. By looking through these, visitors would be able to view short films that illustrated the aspects presented on the wall in further detail. There were also a number of explanatory texts (read by a commentary voice) and images positioned on the wall.

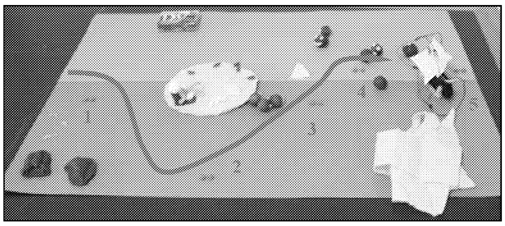

Figure 4. A mechanical model that illustrates the origins of the sulphuric acid problem. The lower half of the wall represents water. The arrow illustrates the motion of the Vasa model. The numbers indicate where "binoculars" containing information can be found: 1) Vasa sinks, 2) the wood absorbs sulphur from waste in the water, 3) salvage, 4) conservation –

sulphuric acid is formed in contact with oxygen, 5) different alternatives for solving the acid problem (the "cage" surrounding the Vasa model at the far right is the Vasa museum).

5.3 Session 3

The goal of the last design session was to refine the concepts and to focus on possible implementation alternatives. Two of the groups from session two participated (groups 2 and 3), together with two of the museum educators. Again, CID hosted the session. Before the session, CID researchers had analysed the concepts and chosen one interesting aspect for each concept. The choices were based on current trends in museum technology and learning research. The researchers had also developed one "what if" scenario for each concept that highlighted issues that were raised in the participants' own evaluation from session two.

The groups were encouraged to continue to refine their concept, while focusing on the highlighted aspects and scenarios. Each group was also presented with a video camera, and were encouraged to record a usage scenario that illustrated their concept. As in the previous session, the groups worked for roughly one and a half hours (including a coffee break). During the last twenty minutes, the groups watched each other's videos and discussed the result.

5.3.1 Refinement: Group 2

Group two had been asked to think about what the interactive stations would contain, and about what would happen if a larger group of visitors wanted the same information simultaneously. The resulting video shows an interested tourist that is given a selection of multiple languages for the voice commentary for an "experiment" at one of the exhibits. It also shows a child that cannot reach the upper part of the exhibit, only to discover "child menus" at a more appropriate height. When these menus are used, the exhibit reconfigures itself to display a content developed specifically for children. The group came up with a simple solution for the problem of large visitor groups: they are given access to one of the museum's tour guides!

5.3.2 Refinement: Group 3

Group three had been asked to elaborate on the content on the wall, and about what would happen if a larger group of multilingual visitors approached the wall at the same time. The result was a number of clarifications to the concept, e.g., the contents of each of the "binoculars", and an "icon-based" chemical formula (figure 5). The video illustrates how the Vasa model moves across the wall, and indicates how each of the individual model parts will move and work.

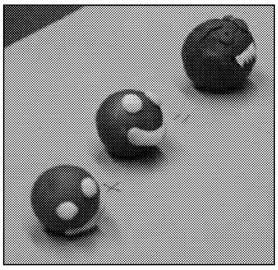

Figure 5. Sulphur + oxygen = "wicked" sulphuric acid.

5.4 Session 4

The students' school hosted the final session, which was devoted to feedback. Eight of the ten students that participated in the previous workshops were in attendance, together with two of their teachers and a member of the museum staff. During the first half of the session, a CID researcher described how the students' work fit into current research on participatory design, museum technology and learning. The KidStory project was also described, together with the main results from [37] and [38]. The presentation also explained how the concepts from sessions 2 and 3 had been analysed (see next section). The second half of the session was devoted to feedback from the students. They were encouraged to evaluate the work method in the same way as they evaluated their own concepts at the end of session 2. This feedback also included a short general discussion on work methods and research in general.

5.5 Concept Analysis

The fact that the groups chose to focus so differently in their concept development was an expected outcome of the work method: it is well-documented that low-tech prototyping methods often result in a wide range of design ideas (e.g., [1][12][36]). In this case, the first group chose to target communication aspects, the second group visual aspects, while the third group chose to focus on context. These three aspects are vital to consider in any museum exhibition [17][29]. It is interesting to note that the groups were not assigned to different topics by the session facilitator (although the topics the groups did address are largely part of the set of "basic requirements" from the first session). The division of topics among the groups was probably largely coincidental.

The first group focused on communication aspects and how to communicate with different audience groups. Their main idea was that different kinds of information databases would provide part of the support for such a communication process – in different languages, and for different age groups. The robot the group describes is something in between an information database and a museum guide, in that it provides an opportunity for individual, private dialogue about the exhibition at the same time as it has access to very detailed information. It is seldom possible for "ordinary" museum tour guides to engage in longer conversations with individual visitors during the tour. Within the museum technology research field, similar kinds of ideas are currently being explored (e.g., [8][30][32]). The group also provided a number of thoughts on technical details. The idea of projecting images directly onto the ship to "illustrate what is going to happen" is particularly interesting, and is reminiscent of recent research within the ubiquitous computing field, research that is just now being introduced into the museum domain (e.g., [2][33][19][28]).

The second group focused on visual aspects and different kinds of participation. The large-scale 3D-animation of the ship serves both as a means for drawing audiences into the exhibition, but also provides visitors with a sort of "compensation" for not being able to walk onto the real ship. The display also presents the focus of the exhibition by illustrating how sulphuric acid is produced in the wood. The smaller exhibits are designed to allow their content to be seen from any direction, which highlight the issue of how museum visitors constantly shift between contemplation and being active, roles that are afforded by all interactive exhibits. One current trend in museum research is to examine how technology can be used to support different forms of participation, and how such participation can be made visible to observing visitors (e.g., [23][21]).

The third group focused on context and temporal aspects. A particularly interesting result of their work is that it questions and extends the originally intended scope of the exhibition. To illustrate, as the group has done in their concept, the entire history of the ship, naturally raises waste recycling and ecology issues, something that is not part of the original exhibition scope. The third group also took a somewhat more pedagogical approach than the other groups. One example is the "formula" where the physical "icons" from their model representing oxygen, sulphur and sulphuric acid are being used both to illustrate the chemical process, and to explain what the icons are (figure 5).

Thus, the groups were able to provide a number of concepts that embody ideas from current trends in museum research. In addition, some of the general ideas (such as projection onto artefacts and 3D displays) are just beginning to emerge and receive attention within museum research. Therefore, our participatory concept development was able to (at least in this case) produce design ideas that are both relevant and extend the initial scope of the exhibition in question.

The amount of resources required was modest: CID spent roughly 24 man-hours preparing and hosting the four sessions. The participants spent approximately nine hours each (excluding travel and the students' initial teaching session at the museum). Approximately $100 was spent on low-tech material.

6. METHOD EVALUATION

The students' written comments on the work method itself (acquired during session 4) can be grouped into the following categories:

The work environment: It is clear that the students felt that the sessions were positive and easy-going: the most frequent positive comment is "coffee breaks"! That a majority of the students feel strongly about the coffee breaks suggests that the breaks do not merely constitute a pleasant opportunity for socialising; they are extremely important for the work method itself (a similar conclusion is drawn in [1]).

Work material and planning: A number of the positive comments were related to working with low-tech material and video camera. However, some of the students also felt that the amount of time available for working was too short.

School issues: Quite a large number of comments deal with the students' relationship to their school. The fact that the students feel that it is positive to "work freely" and "not having to go to lessons" raises some interesting questions concerning the pedagogical methods currently being used in the school. Are the students too constrained in their day-to-day work, and if so, can aspects of the participatory methods described in this paper help? Another interesting issue is that the students who participated in our sessions received notes of absence in their report cards, something that potentially may have a negative impact on their future grades. Thus, in effect, even though the school endorsed the students' participation in the sessions, it also indirectly punished them (albeit in a limited way) for taking part in the activities.

Viewing things differently and contacts with "the outside": Swedish high school curricula rarely allow students to come in direct contact with adults' workplaces. Several of the students that participated in our sessions have mentioned that direct contact with researchers and the museum's personnel have been positive and have led to new ways of thinking about different issues. Thus, at least for these students, our work method has had positive pedagogical side effects (see [31] for a more detailed, similar argument).

Opportunity for influence: The foremost goal of cooperative and participatory design is to empower users so that they are able to influence the design process. Among users, this is – not surprisingly – seen as a mostly positive aspect. In this regard, our findings are not different: we received a number of positive comments from the students with respect to the ability to shape and influence a real museum exhibition.

Our documentation of the work process has also identified a number of challenges and aspects that could be improved:

Including a member of the museum's educational staff in each group had both positive and negative outcomes. The main benefits were that the work of the groups became an amalgamation of ideas from both students and educational staff, and that the adults were able to resurrect the discussion when it dwindled. The main drawback was that the adults sometimes tended to exert too much control over the general direction of the work. The difficulty of establishing roles in participatory processes seems to be rather common and appears to become less significant as the participants gain experience in working together (see, e.g., [35][18]). Allowing the museum personnel to partake in preparatory educational activities regarding their expected roles in the design activities might help.

Sometimes, the researchers influenced the work of the groups unintentionally. For example, in session 2 the low-tech material had been positioned at one end of the table around which the participants gathered. As a result, the students tended to work with the material that happened to be closest to them. An interesting area for further research is to attempt establish to what extent the available material (and how it is being introduced) shapes the outcome of the work.

It was hard for our participants to avoid reasoning about how "implementable" their designs were. For example, a number of the negative aspects from the students' concept evaluation (at the end of session 2) are related to the implied cost of the scenarios, even though they were explicitly asked to disregard such issues.

During the low-tech sessions, each group divided the construction work among its members after a short initial discussion. As a result, some of the students were "marginalized" in the sense that they focused solely on construction and did not take part in any of the ensuing design discussions. Thus, our low-tech approach has the ability to both focus the work for some participants, and to draw the attention away from the discussion for others.

The groups were given too many tasks to solve in session 3 (video recording, scenarios, and the evaluation data). This caused some confusion, and the groups had difficulties focusing on their work from time to time.

7. FUTURE WORK

Our partner museums are, so far, very pleased with our new participatory concept development and evaluation methodologies. At the time of writing, the Museum of Science and Technology is preparing to use our evaluation method to assess the rest of the exhibits in its Science Centre gallery, while the Vasa Museum has decided to work with CID to produce an exhibit prototype based on the students' concepts. If the evaluation of the prototype is favourable, it will be finalized and included in the large-scale exhibition. Also, the students' school has expressed an interest in learning more about participatory methodologies. The next step is to determine whether visitors can be involved even further in the design process, for example, during content development or exhibit design.

The fact that participatory design is able to produce high-quality user-oriented information technology does not necessarily mean that it can support design processes within other domains. Thus, there is a need for evaluating and validating the outcome of such attempts, not only with respect to the products of the design process, but also with respect to how the different stakeholders and participants feel about their participation. This is especially important within the museum domain, where current design practices have been developed and established over a long time period. It is our belief that the project described in this paper has taken the first steps towards such an introduction and evaluation.

8. ACKNOWLEDGMENTS

We are very grateful for the contributions made by the workshop participants from the Åva high school in Täby, and for the contribution made by the staff of the Museum of Science and Technology and the Vasa Museum. We would also like to thank Björn Thuresson, Sinna Lindqvist, Bosse Westerlund, Helena Tobiasson, Sten-Olof Hellström, John Bowers, Yngve Sundblad, Sören Lenman and the rest of our colleagues at CID. The work described in this paper is funded by SHAPE, a project within the European Union's Disappearing Computer initiative, and by VINNOVA, the Swedish Agency for Innovation Systems.

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Paper C

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École du Louvre
8 - 12 septembre 2003

THE WELL OF INVENTIONS – LEARNING, INTERACTION AND PARTICIPATORY DESIGN IN MUSEUM INSTALLATIONS

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« Acte publié avec le soutien de la Mission Recherche et Technologies du Ministère de la Culture et de la Communication »

Abstract

This paper is concerned with how research on interaction principles, participatory design and museum learning can come together to inform the design of technology-intensive mixed-media museum installations. The paper has two main contributions. First, it presents a novel collaborative interaction technique and illustrates how it can be applied in a museum setting. Second, a new exhibition evaluation methodology adopted from participatory design is presented and assessed. The paper also describes how these contributions have been applied in the production and design of The Well of Inventions, a mixed reality installation co-developed by the Centre for User Oriented IT Design and the Museum of Science and Technology in Stockholm, Sweden.

Keywords: Collaborative Interaction Techniques, Evaluation Methodologies, Museum Learning Research

1. Introduction

Recent research on museum learning suggests that knowledge acquired by visitors during their visit can be highly subjective: personal motivation and previous knowledge interact with socio-cultural and physical factors to determine the learning outcome. We are not in a position to claim that such an epistemology is necessarily correct. However, we argue that it can provide inspiration for novel museum exhibition designs, and shall describe the design and implementation of a museum installation, The Well of Inventions, where a novel collaborative interaction technique we have developed has been combined with an open-ended socio-cultural educational goal.

We evaluated our installation in two different ways. We began by carrying out a standard summative evaluation using behavioural observation and interviews, but although this form of evaluation provided useful information, we felt that it did not capture a wide enough range of improvement suggestions from our visitors. Therefore, we decided to adopt an evaluation/brainstorming workshop methodology from participatory design research. The data provided by the methodology turned out to be largely consistent with the other evaluation methods and it also provided us with a large number of design suggestions.

The rest of the paper is organized as follows. Section two contains a brief overview of human-computer interaction research and provides a selection of relevant previous work in that area. It also contains a review of some recent museum learning research and describes how this has influenced the design of The Well of Inventions. The installation itself is described in detail in section three. Section four deals with the evaluation of the installation and introduces our workshop evaluation methodology. Finally, section five contains a discussion of our results.

2. Previous Work

Human-computer interaction (HCI) research can be defined as the study of human factors in the human-computer interaction process, including research, design, development, and evaluation of interactive computing systems. Its focus is on human communication and interaction with computer systems, and typically combines contributions from computer science, behavioural and cognitive research and systems design. During the last few decades, contributions from end users have also become increasingly important. Much of the research within HCI has traditionally been focused on ergonomic aspects and cognitive psychology, with the aim of providing an understanding of basic principles of interaction (Schneiderman, 1998). This work has resulted in a number of models that relate different human psychological functions to aspects of the interaction with the computer and a wide range of guidelines for user interface design.

During the early 1980s, usability developed as a major topic in HCI research. The development of usability as a new research area can be seen the result of an increasing concern for factors such as social aspects, work processes and the relations between computer applications, users and workplace (Bannon, 1991). Usability research thus deals with interaction in specific contexts and as a result, the focus is typically on experienced users and their work processes they encounter professionally rather than on novice users and general settings. Usability research also has a strong tradition of involving users in the design of new tools to support their work, the rationale being that the experienced end user is the person likely to know most about the challenges and problems that appear in his/her work. This has resulted in a range of new design methodologies that involve users to varying degrees.

The development of usability research in HCI can be seen as the direct result of a number of action-oriented research projects initiated in Scandinavia in the 1970s, often collectively referred to as cooperative design or the Scandinavian tradition in systems design (Greenbaum and Kyng, 1991; Iivari and Lyytinen, 1998). The first cooperative design projects were conceived of as a way to allow workers to influence how new technology should be designed and introduced into their workplace organization. However, after cooperative design was introduced in the United States as participatory design in the early 1980s, the research has focused less on workplace organization issues and more on the development of methodologies for involving users in systems specification and design (e.g., Muller et al., 1993; Beyer and Holtzblatt, 1998; Druin, 1999; Taxén et al., 2001; Bødker et al., 2000). Many of the methodologies from cooperative and participatory design tend to produce a large range of design ideas and suggestions from users and therefore, we believe that the adoption of such methodologies for the museum domain might provide new opportunities for dialogue between museums and their audiences. In section four, we describe how such a participatory methodology was used to assist in the evaluation of The Well of Inventions.

Contemporary HCI research is also often concerned with how different kinds of technology and devices can provide novel, alternative ways of interacting with computers. Examples of topic areas that have grown out of such research include ubiquitous computing (e.g., Weisner 1991) and augmented environments (e.g., Wellner et al. 1993). The SHAPE project (http://www.shape-dc.org/), of which the authors are participating members, belongs to this general area of HCI research. SHAPE is a part of the European Union's IST/Disappearing Computer initiative and is devoted to understanding, developing and evaluating room-sized assemblies of hybrid, mixed reality artefacts in museums. The project has produced a number of exhibitions and installations that combine interactive visual and sonic material with physically present manipulable devices

(Bowers, 2001; Stanton et al., 2003; Fraser et al., 2003). The Well of Inventions is part of SHAPE's second year project deliverables and is a direct continuation of ToneTable, a smaller installation that was produced during the project's first year.

ToneTable

ToneTable is a room-sized installation that consists of a rectangular table in its centre with a surrounding multi-speaker array. Activities at the table influences both computer graphics projected onto the table surface and the mixing and spatialisation of sound emitted from the loudspeakers (Bowers, 2001). Thus, the display surface and the sound environment are the main ways in which participants encounter the installation: the supporting computer technology (workstations, keyboards, monitors) is hidden. For reasons of simplicity, we decided to use trackball devices for the user/surface interaction rather than to attempt to follow the users' gestures through video-based tracking or through a touch-screen interface. The trackballs are positioned at the centre of each side of the table, which allows for up to four users to interact with the application simultaneously.

The users interact with ToneTable by manipulating a watery virtual medium projected onto the table (figure 1). Because we wanted to encourage collaboration between several users interacting simultaneously, we attempted to design the dynamics of this medium in such a way that individuals acting alone would gain some benefit from their activity, but that combined collaborative efforts of two or more users would enable features that would otherwise be difficult to obtain. Moving within the virtual medium produces ripples radiating out from a position given by each trackball. The superposition of two trackball positions yields ripples with a summed magnitude. Following elementary wave mechanics, sometimes these ripples cancel and sometimes they reinforce, producing a combined wave of greater magnitude than either participant alone can produce.

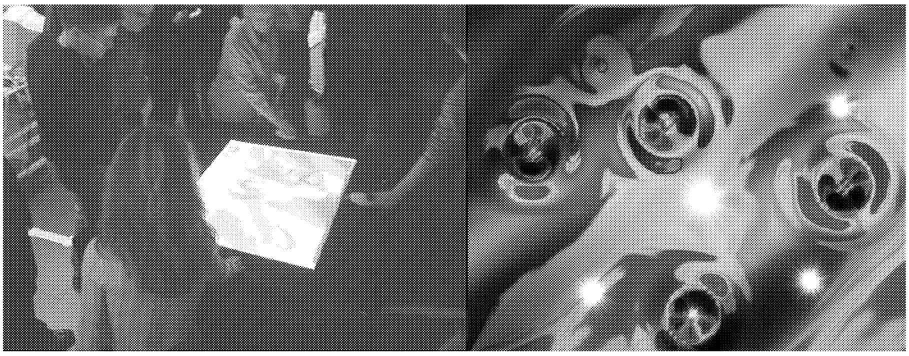

Fig 1: ToneTable.

In addition, a number of star-like objects are floating on the watery surface, each of which is associated with a sound. The visual position of the object is mapped to a spatial location in the audio speaker array (four surrounding the table and four beneath the table), so that the sound "follows" the object around the room. The behaviours of the floating objects are influenced by the amount of virtual force they experience: smaller amounts of force move the objects away from the trackball positions, while a large amount of force (as produced by two or more ripples) sends the objects into a circular orbit. Apart from producing a new visual feature, the orbiting also strengthens the impression of spatial movement of the corresponding object sound.

The ToneTable approach to interaction, co-present collaboration through a shared virtual medium, thus avoids switching interaction medium or mode to support collaboration, i.e., the users do not have to do different things or use new technical features in order to collaborate. With ToneTable, the interaction mechanism remains the same whether collaboration takes place or not (for an alternative approach, see Benford et al., 2000).

In spite of its simplicity, ToneTable provided us with a number of interesting areas for further exploration. It introduced a novel concept of collaboration and it successfully integrated an interactive graphical display with spatialised sound. The trackballs turned out to be a much more expressive device than we had anticipated: our visitors used at least six different types of gestures to interact with the watery surface, including flicking, circular rubbings and careful positioning using the index finger. We also observed a number of different kinds of verbal and non-verbal collaboration, including coordinated efforts to push the sound objects into orbit and "cursor chasing". ToneTable also turned out to be very straightforward to use: no special instruction or descriptive text was necessary to begin using it. These were features we wanted to retain in The Well of Inventions. However, we felt that a less abstract content would be more appropriate for the museum setting and as a result, we turned to current museum learning research in an attempt to identify a suitable approach to introducing such content.

Museum Learning Research

It seems that the educational design of many museum exhibitions is inspired by communication theory and different adaptations of Shannon's (1948) mathematical model of transmission of written messages. Shannon's model was first introduced to the museum domain in the 1960s, and appear to have influenced exhibition design to various degrees ever since (Hooper-Greenhill, 1994). Typically, it is assumed that the museum staff conveys messages or concepts to visitors through an exhibition design, and that different factors may enhance or interfere with the process (e.g., Dean, 1994; Lord and Lord, 2002). However, there seems to be a growing body of recent museum learning research that argues that the adoptions of Shannon's model are too simplistic. The main criticism appears to be that these models tend to neglect that learning may be dependent on the previous knowledge and interests of individual visitors, and on different sociocultural relations between visitors, staff and the set of communities to which the museum's activities are related (e.g., Hein, 1994; Hein 1998; Hooper-Greenhill, 1994).

This critique has resulted in the development of a number of alternative models of museum communication and learning. These are typically more holistic in nature and attempt to tie together issues such as the visitor's encounter with specific artefacts with how the museum contributes to the general knowledge of different communities (e.g., Hooper-Greenhill, 1994; Falk and Dierking, 2000). Thus, the challenge for any exhibition that is designed in accordance with these alternative models appears to be to provide for visitors with a wide range of backgrounds, previous knowledge, motivation and interests, taking part in a variety of social circumstances. It is perhaps not surprising, then, that many authors seems to emphasize aspects such as multiple learning modalities, opportunities for visitors to compare and contrast familiar concepts with new information and the presentation of novel perspectives on familiar objects (e.g., Caulton, 1996; Csikszentmihalyi and Hermanson, 1994).

Our approach to the educational design of The Well of Inventions was to attempt to avoid enforcing any specific didactical methodology. Instead, our installation is designed to provide a foundation from which different learning activities can be built. The design attempts to do this by leaving the choice of how to take advantage of the educational possibilities it offers to the visitors and museum staff. Thus, the educational goal of The Well of Inventions can be characterized as to attempt to encourage discussions on a particular topic relevant to the Museum of Science and Technology. We have attempted to introduce content into The Well of Inventions in such a way that that the opportunities for collaboration offered by the interaction principles developed in our ToneTable work encourages discussions of the content as well. We wanted our installation to be "hands-on" in the sense that it could be accessed directly without the need for written instruction, and we felt that it was important to preserve the sense of natural engagement that visitors often show when they encounter an interesting or mysterious object. Thus, we chose to display the written information in an area adjacent to but separate from the main installation room – the installation itself contains no written text or instruction whatsoever.

3. The Well of Inventions

The content and design of The Well of Inventions was developed in cooperation with the staff of the Museum of Science and Technology. A museum representative was part of the design team throughout the duration of the production and took part in continuous discussions on pedagogy, design and implementation. The topic selected for the installation was chosen with the help of a survey that was sent to all members of the museum staff. The survey asked the staff to identify important artefacts in the collection and many answers indicated objects in the museum's Machine Hall. This hall is a large hangar-like gallery containing steam engines, bicycles, airplanes and cars. Many of the objects and machines in the gallery share a common trait: they make use of propellers and/or turbines in different ways. Furthermore, the gallery also contains a number of historically important turbine and propeller specimens. Thus, the installation was designed to indicate, as a starting point for discussions, that there is a relationship between turbines and propellers and the medium in which they are used (c.f. figure 2), and that the Machine Hall is a resource for further information on the subject. Although the target audience for the installation is high-school students, the topic of dynamics has the advantage of being communicable to a larger range of age groups: with younger children the discussion could be about the usage of turbines and propellers in different forms of machinery, while for adolescents and adults the discussion might be about mechanics or the conversion between different types of energy. It could also readily serve as an introduction into more advanced topics such as that of sustainable energy sources.

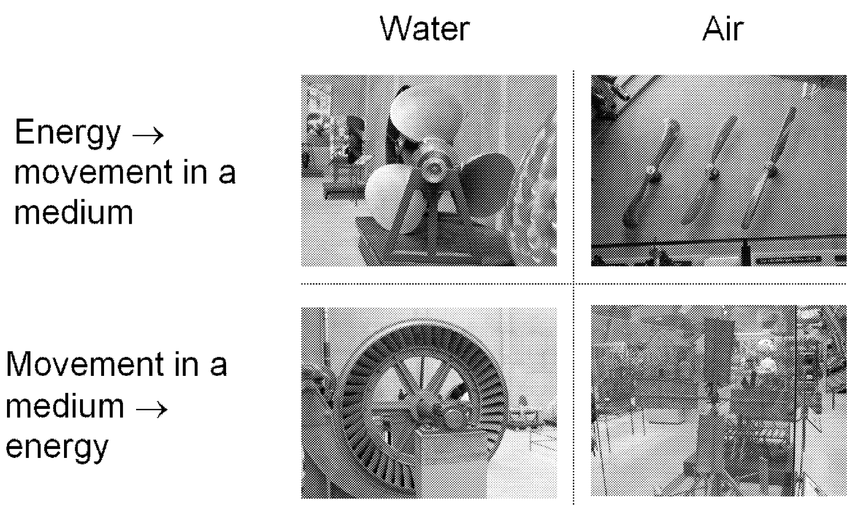

Fig 2: Relationships between propellers and turbines. Fundamentally, a propeller represents a way of converting energy into movement in a certain medium. Conversely, a turbine converts movement in a certain medium into energy.

Before entering the installation room, visitors walk through an antechamber that contains four computer monitors. Each monitor displays a copy of a slideshow with information about the installation and the SHAPE project. Similar to ToneTable, the main installation area is a room with a rectangular trackball-fitted table in its centre and a surrounding speaker array (figure 3). Projected onto the table is a virtual environment depicting an animated, water-filled well. A number of boat propellers and turbines are floating beneath the water surface, moving with the velocity of the fluid (figure 4). These objects are virtual representations of real specimens on display in the Machine Hall. When the velocity of the objects increase, so does their buoyancy, which makes them appear to move towards the water surface. When an object breaks through, it is visually transformed into its corresponding object for air (i.e., a boat propeller is transformed into an airplane propeller, while a turbine is transformed into a set of windmill wings). Above the water surface, the objects move with the velocity of the airflow. Here, their buoyancy is also connected to velocity, so that when an object slows down, it sinks towards the water surface and may again break through. When this happens, it is transformed back to its original appearance.

Fig 3: Table and trackballs in The Well of Inventions.

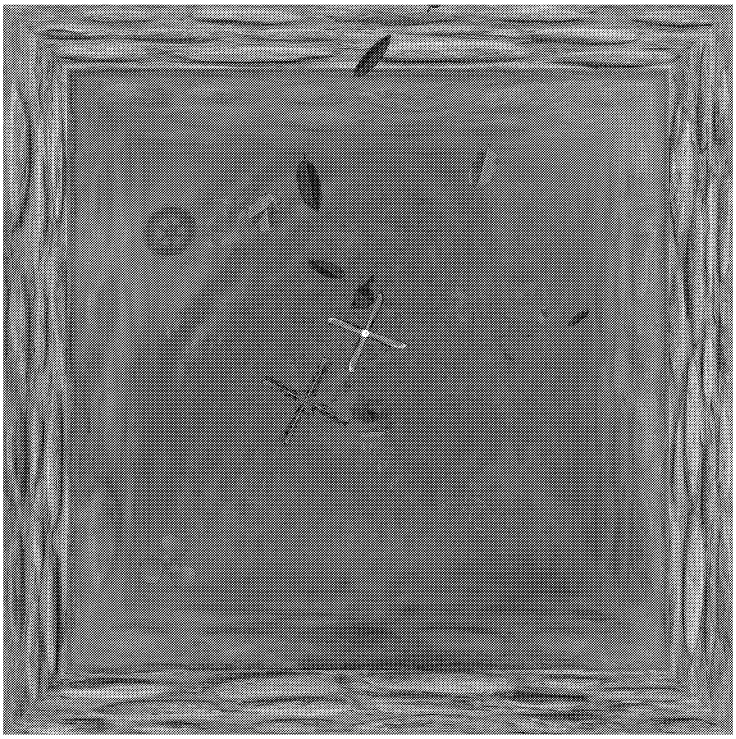

Fig 4: The animated graphical projection in The Well of Inventions.

As with ToneTable, the visitors influence the movement of the objects indirectly through the manipulation of a shared virtual medium (or, to be precise, through two superimposed virtual media: water and air). Each trackball has an associated cursor that follows the trackball movement. As the cursors move, they inject force into the simulations and thus, visitors can more easily push the objects through the water surface if they coordinate their activities at the table. As with ToneTable, each object has an associated sound that is spatialised in correspondence to the object's position in the graphical display. The velocity fields of the water and air are indicated indirectly through underwater weeds and leaves, respectively. In order to provide additional encouragement of higher-level subject discussions, we also decided to include a number of images of machinery where propellers and turbines are used. These images are subtly reflected by the simulated water surface and constitute the inventions referred to in the title of the installation.

Technology

Four trackballs have been fitted into the table and connected to a PC through a standard USB hub. The cursor positions of the trackballs are sent to an Apple G4 that produces the sound (see below) and a Silicon Graphics 330 workstation that renders the graphics. The graphics workstation also runs three simulations that is used to model water wave dispersion, turbulent fluid flow and airflow.

The wave dispersion algorithm is based on (Kass and Miller, 1990) and produces animated water surface waves. We modified the algorithm so that its viscosity parameter can assume different values across the surface, which allows the water surface to appear "sticky" in one part of the display at the same time as having a "flowing" feel in a different part. This feature was used to provide an additional opportunity for collaboration: when two or more trackball cursors are brought together for an extended amount of time, the surface area immediately surrounding them becomes increasingly sticky. An independent two-dimensional simulation approximates the turbulent fluid beneath the surface and is based a Navier-Stokes equation solver (Stam, 2001). When a trackball cursor is moved in a certain direction, a force proportional to the speed of the movement and with the same direction is added to the fluid along the cursor's path, which makes it possible to "stir" the water. The airflow simulation is based on (Wejchert and Haumann, 1991). An air vortex is positioned at the position of each trackball cursor and thus, the airflow is also reconfigured by trackball movement.

The motion of the propeller and turbine objects is governed by rigid body dynamics (Baraff, 1997). The force exerted on the objects is proportional to the underwater velocity field (beneath the surface) and the airflow (above the surface). In addition, a non-penetration constraint is enforced for the objects in order to avoid inter-object intersection (Dingliana and O'Sullivan, 2000). The data from the trackballs and the three simulations produces an image through the superposition of a number of graphical layers, which simulates effects like refraction (Vlachos and Mitchell, 2000) and reflection.

The sound of installation is produced in a similar manner to ToneTable. Applications written in MAX/msp (http://www.cycling74.com) manage the mixing and diffusion of sounds and also calculate appropriate measures of trackball activity and surface perturbation for sonification purposes. We use Pulkki's (1997) VBAP algorithm to spatially locate the object sounds. The sound representing the surface is synthesised using several chaotic oscillators (with each oscillator being a sinusoidal generator that frequency modulates itself via a short delay line) and the moving objects were sonified using looped sound samples. In addition, a sampled transition sound is played when objects cross the water surface. Initially, all the sounds in The Well of Inventions were synthesised using networks of chaotic oscillators, as this has a greater potential for interactivity than replaying sampled sound files. Unfortunately, a fully synthesised solution was beyond the processing capabilities of the computers at our disposal, which made it necessary to introduce recordings of the behaviour of a network of chaotic oscillators. These recordings are played back alongside live synthesised components.

4. Evaluation

The Well of Inventions was evaluated in two different ways. We began with a standard summative evaluation combining behavioural observation and staff/visitor interviews. This provided us with a general impression of the strengths and weaknesses of the installation. However, we felt that the summative evaluation did not provide enough information about the kinds of improvements the visitors themselves would like to see. Therefore, we decided to host a number of workshops whose goal was twofold. First, we wanted to allow a large number of visitors to provide their thoughts and opinions about the installation. Second, we wanted the workshop participants to build from these to develop suggestions for improving its design. In order to ascertain that the workshops generated relevant evaluation information, we triangulated the workshop data with the data from the summative evaluation.

Summative Evaluation

Two researchers observed visitors interacting with The Well of Inventions during approximately 12 hours, spread across 2 days. During this time, about 130 visitors approached the installation. The dwell times varied widely from a few seconds to more than 10 minutes (the longest dwell time we observed was about 30 minutes). Typically, visitors would stay for at least a minute if they "got hooked". A large majority of the visitors that entered the exhibition area also interacted with the exhibition, although a few groups seemed to be unable to spot the trackballs. Of those that interacted with the exhibition, about 20% discovered that it is possible to push the underwater objects through the water surface. It is unclear whether any visitor observed that the objects in the installation are virtual replicas of objects in the Museum's Machine Hall.

It was common for one visitor to discover a feature and demonstrate to other visitors how to use it. On several occasions, children would run off to fetch peers or parents from other parts of the museum, to whom they would then show the feature they had discovered. Children in the ages 10-13 seemed to be more interested in the exhibition than other age groups. These children typically viewed the exhibition as a game: they often (quite enthusiastically) referred to the transformation of objects moving through the water surface as "a kill". Adults showed the least amount of interest, and would often encourage their children to leave the exhibition while the children were still engaged at the table. Many young children were often fascinated by the graphical animation of the water surface and attempted to dip their fingers onto the display to "feel" the water. Older children typically focused on the movement of the objects and attempted to discover the underlying hidden rules of the animation.

Many of the visitors that entered the space as a group discussed the purpose of the installation and the nature of the interaction. They also verbally negotiated the meaning and underlying rules of the motion of the objects. However, the discussions rarely focused on dynamics and the relation between propellers and turbines. Furthermore, few visitors read the text on the computer screens in the antechamber. Occasionally, adult visitors would go back to the antechamber to read the texts after having tried interacting with the installation, but this happened very rarely. Some groups also spent extended amounts of time exploring the physical features of the room, such as climbing the platform or search for the hidden control room.

Two staff members of the Museum of Science and Technology and three visitors were interviewed. The interview data largely confirms the information we obtained through observation. The museum staff members we talked to observed that installation has a strong ability to attract people, even children that would otherwise be hard to encourage to stay and concentrate. Most visitors express a curiosity and want to know more. However, because of the lack of written information, many visitors also leave quickly. Thus, from the point of view of the museum staff, the installation does not really have a specific educational outcome. Its value is more as an indication of the possibilities of technology than as a way of presenting content. The visitors we talked to expressed an interest in the design and implementation of the installation, but also clearly struggled with how to interpret the educational purpose of the installation and how to make use of the opportunities for discussion we attempted to incorporate into its design.

Workshops

Three workshops were held at the Museum of Science and Technology on November 20 and 26, and December 3, 2002. The first of these was organized as an open seminar and had about 15 adult participants. We invited two high-school classes (with about 15 and 30 students, respectively) together with their teachers to participate in the two remaining workshops.

Our workshop procedure is adopted from the future workshop, an evaluation/brainstorming methodology developed within the cooperative design movement for assessing workplace organisations (Kensing and Halskov Madsen, 1991; Bødker et al., 1993). Each workshop begun by allowing all participants to interact with the installation while the facilitator gave a brief talk outlining the installation's implementation and main goals. When every participant had been given a chance to familiarise themselves with the installation, we moved to a quiet conference room (containing tables, chairs and a whiteboard) in an adjoining part of the Museum. Here, the facilitator briefly described the workshop goals and its different stages. Then, the participants were given green and red Post-It notes and were asked to write down at least three positive aspects of the installation on the green notes (one statement per note) and at least three negative aspects on the red notes, and put them on a random location on the whiteboard. This stage took roughly fifteen minutes to complete. When all Post-It notes were positioned on the whiteboard the facilitator asked the participants to collectively attempt to group similar notes together and summarise their content in a heading. After about fifteen minutes, all notes had been accounted for. At this point, we took a fifteen-minute break after which the participants were asked to form groups of about five persons each. The groups were encouraged to examine the whiteboard and try to think of ways in which the negative aspects of the installation could be improved while keeping the positive aspects. Each group was shown to a quiet, private area and were given about thirty minutes to discuss. When the groups had reconvened in the conference room, we spent about thirty minutes talking about what the groups had discussed and what design suggestions they had thought of. A more detailed account of these discussions and the content of the Post-It notes are provided in (Taxén, 2003).

In our interpretation, the data acquired from the observations, interviews and workshops share five common themes. The first theme is that the educational purpose of the installation is perceived as problematic or non-existing. During our observations, visitors would frequently express a sense of puzzlement and curiosity. We also observed visitors discussing the purpose of the installation, and the purpose of the installation is also mentioned in all interviews. 44% of the workshop Post-It notes on negative aspects mentions lack of purpose or difficulty in comprehending the purpose and all brainstorming/discussion groups (in each of the three workshops) raised pedagogical issues.

The second theme is that the audiovisual design of the installation is largely perceived to be successful. During the observations, visitors and especially children were fascinated by the graphics and a majority of the interviewees mentioned sound and/or graphics as positive aspects of the installation. 51% of the workshop Post-It statements related to positive aspects are concerned with design, graphics and sound.

The third theme is that many visitors perceive the installation as engaging and fun. During the observations, we saw that pre-teen children were especially enthusiastic about the graphics and sound, and many visitors spent a large amount of time in the installation area. In the interviews, the museum staff told us that the installation has a strong ability to attract people, including children that would otherwise be hard to encourage to stay and concentrate. 26% of the workshop Post-It notes on positive aspects were related to fun and excitement. The subject was also raised during the brainstorming discussions.

The fourth theme is that the installation has the ability to encourage collaboration. We observed visitors that coordinated their trackball gestures in order to increase the velocity of the water simulation, thus pushing objects through the water surface. Some visitors also cooperated to reproduce the "stickiness" effect. During one visitor interview, the interviewees described how they coordinated their activity by chasing their respective cursor around the display. The workshop statements also mention collaboration (4% as a positive aspect and 3% as a negative aspect). Collaboration was also brought up as a topic during the brainstorming phase of the first workshop.

The fifth theme is that the physical design of the installation environment made the interaction devices hard to spot for some visitors. During the observations, we observed that several visitors left the main installation area without interacting with the installation, quite possibly because they had not seen the trackballs. The issue is also present in the interview data, and 7% of the workshop Post-It notes mentions darkness, difficulty of spotting the trackballs, or difficulty of relating trackballs to cursors as negative aspects. Darkness and/or difficulty of spotting the trackballs were also brought up as issues during the brainstorming phases in all the workshops.

5. Discussion

We would argue that the emergence of common themes in all three types of evaluation data (observations, interviews and workshops) suggest that the workshops did provide relevant evaluation information, and that they might be useful to evaluate other forms of exhibitions as well. Indeed, the Museum of Science and Technology are now independently adopting the methodology for evaluating their science centre exhibits.

However, an important difference between the workshops and the observations/interviews is the broad range of design suggestions we obtained through the workshops. Some of these suggestions were mentioned in all three workshops (e.g., improving the visibility of the trackballs, presenting the background information in a clearer way). This suggests that many visitors share these concerns, which makes them important to act upon. Interviews or questionnaires are good ways of obtaining suggestions from visitors, but we would argue that the workshop format could be used as a complementary method to assist in efficiently acquiring a broad range of detailed such suggestions from large groups of visitor representatives. For The Well of Inventions, the workshops and the summative evaluation demanded similar amounts of resources, but the workshops also provided us with opinions from roughly sixty visitors and the opportunity to engage these visitors in a fruitful dialogue about design and content.

Our evaluation data suggests that The Well of Inventions has the ability to encourage reflection, collaboration and dialogue. For many visitors, it provides a sense of mystery and is perceived to be fun, attractive and aesthetic. Furthermore, it gradually reveals new features as visitors are interacting with it and in many cases the result is long dwell times. We believe that this suggests that the interaction principle of collaboration through a shared virtual medium can be fruitful in museum settings.

On the negative side, our installation fails to communicate its purpose and background and it is perceived to have a questionable (or even non-existent) educational goal. Visitors very rarely perceive the important connection between the contents of the installation and the Museum's Machine Hall. The educational goal of The Well of Inventions was to provide an experience that could serve as a foundation for communication (verbal or non-verbal) between visitors (or visitors and museum staff) on the subject of dynamics. We believe the evaluation data indicates that this goal has been partially met. While the installation does encourage visitors to interact, think and reflect, the focus of the reflection process is typically the installation itself rather than the topic its design is intended to represent. Thus, some form of modification of the installation's design is necessary to guide discussions towards dynamics and machinery. The workshop data provided us with a large number of suggestions of how this could be done, ranging from replacing the computer screens in the antechamber with properly highlighted posters to introducing a narrative into the installation.

We believe that a museum, like any other institution, affords a certain set of socio-cultural conventions. These conventions include visitor expectations about different pedagogical and audiovisual aspects of exhibition design. When experimental installations like The Well of Inventions break these conventions, in this case by allowing information to be portrayed implicitly rather than explicitly in the design, visitors may become confused. Thus, it may be necessary to scaffold the visitor's expectations in such situations so that they know how to approach and understand the exhibition. At the time of writing, we are planning a re-design of The Well of Inventions to this end and a subsequent number of workshops to evaluate the outcome.

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Paper D

Taxén, G. Teaching computer graphics constructively. *Computers & Graphics*, 28(3), 393–399.

Paper D

Available online at www.sciencedirect.com
SCIENCE DIRECT
Computers & Graphics 28 (2004) 393–399
COMPUTERS & GRAPHICS
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Teaching computer graphics constructively

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Abstract

During the last few decades, constructivist-oriented teaching methods have gained increasing support within primary education. This paper provides a short overview of two such constructivist epistemologies and describes a preliminary attempt to apply them in university-level graphics education. While the outcome of the attempt is difficult to evaluate, the reaction from the students raises some interesting issues concerning problem solving and efficiency in general.

Keywords: Constructivism; Computer graphics education

1. Introduction

During the last few decades, many educational practitioners have increasingly turned their attention to constructivist models of learning. These models are substantially different from traditional modernist views of learning in that instead of conceptualizing knowledge as something that is transmitted from the teacher to the learner, they emphasize learners' active construction of their own subjective comprehension. Constructivist pedagogies have been successfully used in learning situations where the acquiring of a deep understanding of a subject is required, although they seem less suitable for memorization or training [1,2].

The philosophy of constructivism can be said to have evolved as a post-modernist reaction against the traditional modernist view of knowledge as something in the mind that reflects or represents a fixed external reality. Instead, constructivists typically claim that at least some—or all—aspects of the world that from a traditional realist perspective are seen as ontological facts, stem from (or consists of) human constructions and social relations. Many philosophical variations of constructivism can be identified, ranging from those that see both the world and our knowledge of it as purely constructed to the more common view that there is a world independent of human beings but that our knowledge of it is restricted to our own constructions [3]. This latter perspective (which is probably the most common among constructivist educational practitioners) can be further divided into two main groups:

- *Cognitive oriented constructivism*, which emphasizes the cognitive mechanisms of individual persons, and
- *Socioculturally oriented constructivism*, which emphasizes the internalization of socio-cultural activities.

Although the two groups stem from different theoretical foundations, it is possible to view them as complementary. In this case, learning can summarized as *a process of active individual construction that occurs when the learner is engaged in a social practice, frequently while interacting with others* [4].

2. Constructivist epistemologies

Cognitive constructivists typically see *organizations of experience* as a fundamental unit of epistemology. According to their view, cognitive structures develop in response to experiences of the world, so that if the current set of structures does not accommodate a specific experience they may, under certain circumstances, be updated to again support a conceptual equilibrium.

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0097-8493/$ - see front matter
doi:10.1016/j.cag.2004.03.006

One of the main proponents of cognitive constructivism is Ernst von Glasersfeld [2], whose model of learning is based on Jean Piaget's notions of *assimilation*, *accommodation* and *action schemes* [5]. An action scheme is a cognitive structure that associates an action with a remembered experience and an expected result. The carrying out of an action scheme proceeds similar to the following:

(1) A current experience is assimilated, i.e. it is compared to remembered experiences to see whether it is an instance of one of them. This process is highly selective: it is prone to disregard items in the perceptual field that does not fit into current cognitive structures.
(2) The associated action is carried out. It can be directed either at sensi-motor level activities or at mental constructs.
(3) The experience of the result of the action is again assimilated.

If the result of the action is unexpected, it leads to a *perturbation* to which one can react with disappointment or surprise. If the initial situation associated with step 1 can still be perceived it can be reviewed, and a new scheme that fit the outcome better can be constructed. This process—accommodation—is equivalent to learning. Thus, in the cognitive constructivist model the only way to acquire new knowledge is through perturbations. It should be noted that because of the selective character of assimilation, perturbations are difficult to achieve: we are (unconsciously) reluctant to break our epistemological equilibrium.

Socioculturally oriented constructivists typically base their work on the writings of Lev Vygotsky and the later work of Ludwig Wittgenstein and often see the *activity of communication* as a fundamental unit of epistemology [6,7].

Wittgenstein rejected the modernist view of units of language (sentences, phrases or words) as the carriers of unique meaning. Instead, he introduced the concept of *language games*—patterns of linguistic behavior embodied in types of social activity—and proposed that meaning is equivalent to the role of utterances in such games. That is, to understand the meaning of an utterance is equivalent to acting or responding to it in a way consistent with the implicit rules of the particular language game in which one takes part. Such rules are defined by the social context in which the game is played and vary with the communities, situations and participants involved. Moreover, the rules may change over time, allowing the game to grow, change and lead in unanticipated directions [8]. If the rules are not followed, communication breaks down and the participants have to negotiate another way of continuing the exchange.

The Soviet psychologist Lev Vygotsky developed a psychological model around the concept of *internalization*, i.e., every function of a child's cultural development—including voluntary attention, logical memory, and the formation of concepts—is transformed from being a social, public action to an internal, psychological activity. Since every higher mental function is acquired through such social interaction with others, Vygotsky argued that the way people think and reason is uniquely shaped by their previous relationships with others [9]. Through participating in social activities, children—and adults—successively learn to participate in a growing range of different social contexts and language games. Vygotsky also noted that children that encounter a problem too difficult for them to solve on their own, often manage to solve it if they receive assistance from a more knowledgeable person. He used the term *zone of proximal development* to indicate the difference in "developmental level" between these two persons.

3. Constructivist pedagogies

There are a number of descriptions of how constructivist epistemologies can be applied in classroom teaching practice. In Von Glasersfeld [2], for example, the following guidelines are suggested:

- The teacher should aim to maneuver the learners into situations where their network of explanatory concepts turns out to be unsatisfactory, while remaining as neutral as possible. The learners' current knowledge is not "wrong", nor is the teacher's view "correct"; the learners are simply interpreting the world according to their current epistemological equilibrium.
- In addition to being familiar with the subject in question, the teacher needs a repertoire of didactic situations in which the corresponding concepts can be applied, situations that ideally evoke the learners' spontaneous interest.
- When learners solve problems, their work and effort should be acknowledged, regardless of whether the solutions are viable or not. Otherwise, their interest in future work may disappear.
- In order to be able to appropriately challenge the learners' current mental concepts, the teacher must have some model of those concepts, i.e., the teacher must know something about the learners' current knowledge.
- The most straightforward way to encourage reflection is by having the learners talk about what they are thinking. Thus, problem solving should ideally also initiate conversations.

In Twomey [1], the following additional guidelines are presented:

- Learning is equivalent to the development of individual learners' understanding. Therefore, they must be allowed to raise questions, generate hypotheses and test them for viability.
- The learners must be given time to reflect so that they can mentally organize and generalize what they have learned. Examples of techniques to support this process include journal writing and the creation of representations in multiple forms of media.
- The learners should be responsible for defending, proving, justifying and communicating their ideas to the rest of the classroom community. An idea is only accepted as viable when the community has reached consensus.

Socio-culturally oriented constructivists often place a large emphasis on *scaffolding*, i.e., methods where the teacher guides the learner towards a solution to a problem, or where the learner solves a problem in collaboration with peers. In Dalton [10], the following principles are emphasized:

- Joint productive activity: teacher and learners produce together.
- Developing language and literacy across the entire curriculum.
- Connecting school activities to the learners' lives.
- Teaching through instructional conversation.

For some socio-culturally oriented constructivists, however, the concept of classroom practice is problematic, because it implies that knowledge can (at least in part) be socially *decontextualized*, i.e., that knowledge acquired in one context can be reapplied in a different context. In practice, however, such decontextualization may not always be the possible, especially not for advanced topics. Thus, these educationalists focus on the relationships between the school and the communities of practice where the knowledge is to be applied, and how the learners come in contact with those communities [11].

The constructivist pedagogical focus on dialogue and learner participation puts a number of traditional didactic methodologies in question [12]. In lecturing, for example, the lecture necessarily follows the speaker's line of thought (since he or she created the lecture)—but this does not necessarily mean that the narrative matches the listeners' conceptual explanatory framework. Furthermore, the physical circumstances of lecturing may discourage questions and dialogue. Often, the number of participants is large, which can make a listeners feel that their questions are "stupid". Also, the speaker usually has a tight time schedule, which necessitates short answers to questions that arise. Thus, one cannot assume that listeners "learn" what the speaker is presenting. However, this does not at all imply that lectures have no place in constructivist-oriented education. On the contrary, Ben-Ari [12] points out, lectures can be very suitable indeed for raising an interest, presenting demonstrations, and for providing overarching frameworks to which learners can relate when they are engaged in other learning activities.

4. Technology-based learning tools

A multitude of computer-based tools designed to explicitly support different constructivist pedagogies have been available since the early 1980s, and a number of researchers have presented guidelines for the development of such tools (e.g., [13,14]). Examples include multimedia CD-ROM products like Mulle Meck, (http://www.barnlandet.se/mulle/), children's programming languages like LOGO [15], re-usable components like E-Slate (http://e-slate.cti.gr/), and systems that allow learners to gain access to the concepts, problem solutions, and jargon used by experts [16]. More recently, a number of collaborative environments based on virtual reality and augmented reality technologies have been introduced (e.g., [17–20]).

The number of educational tools designed explicitly for constructivist-oriented teaching of modern interactive computer graphics is much fewer. A common didactical approach is to use books and on-line or off-line educational components [21,22] or higher-level systems like Alice [23] to give students a theoretical foundation, and a low-level programming library like OpenGL or Direct3D for practical exercises, projects and assignments.

At the Center for User-Oriented IT Design, we are developing a system called Wasa that it is mainly used for prototyping of moderately complex graphics applications. Wasa allows the graphics hardware pipeline to be configured interactively through XML shader files in a way similar to RenderMonkey (http://www.ati.com/developer/). This allows the functionality of the graphics hardware to be *exposed incrementally* without the need for explicit programming, so that its fundamental parameters can be manipulated first, and additional detail can be revealed later as the need arises. I believe features similar to this could be used in constructivist-oriented teaching to provide the learners with a useful problem manipulation space (cf. [14]).

5. Critique of constructivism

The constructivist movement is not uncontroversial and has been heavily criticized, both with respect to its philosophical (e.g., [24]) and epistemological and psychological (e.g., [25]) roots.

The critics' main concern is the tendency among many constructivist-oriented pedagogical practitioners to overemphasize aspects of the constructivist stance. Examples include the claim that all knowledge is specific to the situation in which it is acquired and therefore cannot be transferred between tasks, or the claim that any form of systematized practice task has a negative influence on motivation and therefore inhibits the learning process. Such claims, critics say, may ultimately encourage teachers to refrain from making use of explicit instruction and practice in lieu of inefficient *discovery learning*, i.e., a pedagogy where the learners are given full control over their studying activities.

Furthermore, critics challenge the advocates of constructivism to show that their proposed way of approaching education leads to more knowledgeable students. Even when constructivism is applied in a didactically sound manner, recent studies within cognitive psychology suggest that the academic performance of students that were exposed to a constructivist-oriented pedagogy in their early school years is not significantly different after college graduation than that of peers taught using traditional didactics [26]. Also, the kind of collaborative learning often advocated by socioculturally oriented constructivists may be difficult to facilitate in practice: there is a risk that students divide the work between themselves instead of solving the problem together.

Finally, constructivists are typically uncomfortable with traditional methods for evaluating learning outcomes and thus often advocate methods of a more qualitative character. However, the critics point out that such qualitative methods may cause social, cultural and intellectual bias that, in turn, might lead to an unfair assessment of the learners' achievements. I shall return to the issues of efficiency and assessment in the discussion section.

6. Constructivist teaching of computer graphics

As an initial attempt to determine whether a constructivist-oriented epistemology might be suitable for university-level computer graphics education, I organized a workshop called 3D Graphics for Dummies in December 2002. The educational goal of the workshop was to help the participants acquire an understanding of the graphics hardware pipeline and the fundamental concepts of hierarchical transformations and animation. Since Wasa allows easy modification of graphics hardware configurations without the need for programing, I decided to attempt to use it as a learning environment for the workshop. Thus, the only explicit prerequisite was that the participants had some previous experience with computers.

The workshop had about 20 participants. It was approximately 3 h long and was divided into two parts. The goal of the first part was to guide the participants in constructing a theoretical understanding of the graphics pipeline, while the second part allowed the participants to apply their knowledge in practice. From a traditional educational perspective, it might have been appropriate to initiate the first part of the workshop with a lecture describing the pipeline. As mentioned above, however, constructivist pedagogy suggests that for the purpose of supporting learners in their construction of conceptual understanding, this may be an inefficient way of proceeding. Thus, I instead chose an approach where my role was to guide the participants in constructing a conceptual image of *what components the graphics pipeline is likely to have, given that it has certain capabilities*.

I began by running a Wasa program that draws an image of two triangles, one in wireframe and one filled with a solid color (I used a projector to allow the participants to see the output of the program). I then asked what the computer must be able to do in order generate such an image. After some discussion, the notion of a rasterizer was suggested: a component that takes vertices as input and generates sets of pixels as output. At this point, I drew a text box containing the word *rasterizer* on a whiteboard. The next step was to show the participants a rotating wireframe model and ask how such a thing as rotation could be accomplished. This led to the notion of transformation of vertices. Thus, I drew a corresponding text box containing the word *transformation* on the whiteboard and connected it to the rasterizer. Concepts like image plane projections, z-buffering, lighting, texturing, alpha blending, stenciling and environment mapping were developed analogously. The end product was an image on the

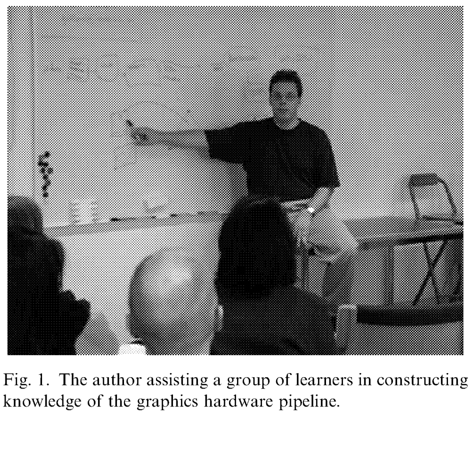

Fig. 1. The author assisting a group of learners in constructing knowledge of the graphics hardware pipeline.

whiteboard illustrating the main components of the modern graphics hardware pipeline (Fig. 1). The whole process took about 1 h. Sometimes, the participants would "get stuck". In such cases, I asked them to attack the problem in groups of two. At other times, I would do "live" rewriting of my example programs in order to clarify a line of reasoning or in response to questions.

The second part of the workshop was concerned with applying the concepts from the first part in practice. The participants were divided into groups of two and each group was presented with a computer running Wasa. In addition, each group was given a compendium containing a Wasa overview and 12 exercises. The aim of the exercises was to encourage the learners to solve a number of relevant problems related to the manipulation of the graphics pipeline. The problems included:

- Move the camera and light sources to different positions and change their properties,
- Make a model rotate twice as fast,
- Add a texture to a model.

During this phase of the workshop, I would answer questions from the groups and guide them towards the solution of the problems if necessary. After 2 h, most of the participants had successfully completed a majority of the exercises.

Although there was not enough time to do any detailed evaluation of the educational outcomes of the workshop (we were not allowed to continue beyond 3 h), I have some anecdotal evidence that it was largely successful. All participants thought that the fist part was rewarding, although a few were concerned with the variations in tempo: the "flow" of my presentations of problems were interrupted by the comparatively long "awkward silences" when people were thinking. Furthermore, most participants expressed an understanding of the graphics pipeline and seemed to enjoy the exercises, although some thought the formulation of a few of the problems were a bit unclear.

As I was unable to interview any of the workshop participants in depth or assess their graphics knowledge through other means, it was not possible to draw any strong conclusions about the nature of the understanding they acquired. In addition, due to the time constraints, the participants were not given the opportunity to discuss their understandings with the entire group, nor were there time to talk about the participants' individual backgrounds and personal interests. However, because the approach towards introducing the graphics pipeline seemed promising, I wanted to see if and how it would scale to larger groups. Therefore, I decided to attempt to introduce the technique at one of the introductory courses on computer graphics I teach at the Royal Institute of Technology.

7. Extension experiment

All introductory courses on computer graphics at the Royal Institute of Technology treat OpenGL in the same manner. Basic interaction principles and window system fundamentals are introduced in a lecture on GLUT (http://www.opengl.org/developers/documentation/glut/), followed by two OpenGL lectures that describe the graphics hardware pipeline and the basic functionality of OpenGL (geometry specification, transformations, lighting, textures and buffer tests). The students are also given a laboratory assignment where they use OpenGL to animate a hierarchical model.

Thus, I replaced the first OpenGL lecture by the "constructing the graphics hardware pipeline" activity. Roughly 30 students with varying backgrounds and two graphics teachers (including myself) were present. The procedure was similar to the workshop. I first introduced each pipeline stage concept through a demonstration program (e.g., Fig. 2). I then posed a problem to the participants (e.g., "What algorithms or mechanisms could we use if we want to remove hidden surfaces like in the demonstration program"). I encouraged the students to form groups of three to four persons and allowed them to discuss the problem for 5–10 min. Meanwhile, both teachers were available to answer questions and provide clarifications. Finally, one of the groups was selected and asked to present their

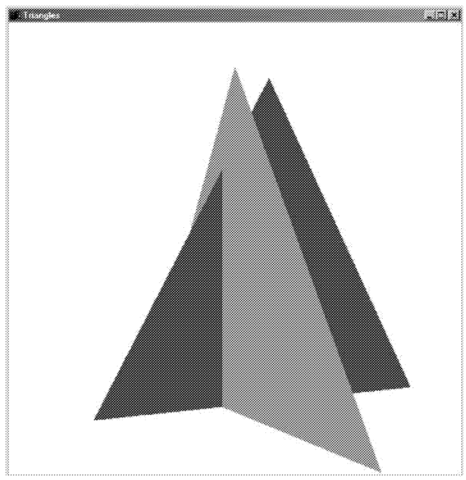

Fig. 2. Demonstration program illustrating depth buffering. The light triangle is rotating, while the other remains stationary.

solution(s) to the rest of the participants. After the ensuing general discussion, I would draw the pipeline stage on the blackboard, as in the workshop. The procedure was then repeated for the next pipeline stage.

The examination methodology for the OpenGL material in the introductory graphics courses is through laboratory assignments. There were no large changes in assignment completion rate for the course after the constructivist-oriented technique was introduced: 90% as compared to 92% the previous year. Nor were there any large changes in the written examination results for the rest of the course: 76% of the students passed the exam as compared to 78% the previous year.

In order to assess what the students felt about the alternative technique, I asked them to answer a questionnaire, dealing with issues such as whether the alternative technique should be used in future courses and what was felt to be positive and negative about it. Roughly 30% of the participants answered the questionnaire. Out of these, 36% wanted to keep the technique, while 82% preferred ordinary lecturing (the sum is larger than 100% because some students gave an affirmative answer with certain provisos).

The returned questionnaire also provided a number of interesting comments on the positive and negative aspects of the constructivist-oriented approach. Among the positive aspects were the following:

- "You have to think for yourself",
- "You became involved in the task",
- "You're activated",
- "Students are allowed to talk".

The negative aspects included:

- "Students didn't have enough background knowledge—too difficult",
- "Too much time for discussion—students lose focus",
- "Don't know the other students",
- "Wait for the others",
- "Ineffective".

8. Discussion

Even if it is impossible to draw any strong general conclusions from the questionnaire, it is clear that a significant number of students felt that the constructivist-oriented technique replacement was a failure. At the same time, the technique appears to encourage students to think, become involved and allow for a discussion involving everyone. On the one hand, it may very well be that improving the circumstances of the activity itself (such as moving to a more appropriate physical location, learning more about the background knowledge of the students, dividing the activity into a number of smaller parallel sessions, and changing the details of its implementation) would improve the acceptance rate. On the other hand, I believe that the outcome of the questionnaire raises some deeper fundamental issues concerning the higher-level education system itself.

For example, under the "general comments" heading in the questionnaire, one student writes

"I go to the lecture to learn from the teacher, I do problem solving much better at home."

while another student feels that it was a

"Waste of time to attempt to come up with a solution to a problem you don't have a clue about how to solve."

Here, my interpretation is that the students in question feel that practicing graphics-oriented problem solving skills through a group-based activity was inappropriate. With regards to efficiency, one student writes

"A good lecturer tells me what I have to know to complete the project assignments in an efficient way."

My interpretation of this view is that here, efficiency is thought of in terms of how readily the students manage to pass the course requirements. Thus, it may very well be that some students feel that my constructivist-oriented activities—activities that were designed to highlight abilities like problem solving and taking an active part in activities—are in conflict with the goal at hand (i.e., passing the course).

There is evidence that this way of reasoning is not uncommon among students in higher-level education (e.g., [27]). The most likely reason is that students must constantly balance two conflicting demands: the necessity to manage large amounts of information over short time periods, and the slow, painstaking development of an understanding of that information. In situations where the student is forced to choose between the passing of an exam through memorization of facts and spending a large amount of time acquiring a deeper understanding and problem-solving skills, most students are likely to choose the former alternative. As a result, it is quite possible for a student to pass an exam without a deeper understanding of the subject in question.

But if standard assessment methods like written exams encourage students to *avoid* the development of deeper understanding, like the work of Svensson suggests, then using measures like academic performance to evaluate the outcome of constructivist-oriented pedagogies, as is done in the work cited by Anderson et al. in their critique of constructivism mentioned above, may not be entirely appropriate. For example, Bartlett et al. reports [28] that graduates of the socially constructivist-oriented primary school under study are well prepared in conceptual understanding, time/resource management, social maturity, and group leadership (p. 46). Such skills are obviously desirable, but appear to be difficult to measure through academic performance assessment methods alone. In the work just mentioned, Bartlett et al. advocates a combination of standardized tests, classroom tests (for spelling etc.), teacher observations and self-evaluation. Adopting such involved assessment techniques for university-level teaching with its large student groups and limited resources remains an open challenge.

Thus, I believe that while constructivist pedagogies and the didactical guidelines they advocate might very well be of use in computer graphics teaching, it is quite unclear whether they actually benefit the students under the current educational system with its exam-based performance measure. It may very well be that it is necessary to introduce more sophisticated assessment and examination methods before constructivist pedagogies can be made truly efficient in higher-level education.

Acknowledgements

Thanks to John Bowers and Ambjörn Naeve for their participation in many useful discussions of pedagogy and education politics, and to Pär Bäckström öm and Olle Sundblad for helping me develop Wasa. This work has been partly funded by SHAPE, a project within the European Union's IST Disappearing Computer initiative.

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Paper E

Taxén, G., Bowers, J., Hellström, S.-O., and Tobiasson, H. Designing Mixed Media Artefacts for Public Settings. In Darses, F., Dieng, R., Simone, C., and Zacklad, M. (Eds.) *Cooperative Systems Design. Scenario-Based Design of Collaborative Systems.* Amsterdam: IOS Press, 2004, 195–210.

Paper E

Designing Mixed Media Artefacts for Public Settings

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Abstract. This paper describes how principles which are emerging from social scientific studies of people's interaction with mixed media artefacts in public places have been used to support the development of two installations, the second of which is a long term museum exhibit. Our principles highlight the design of 'emergent collaborative value', 'layers of noticeability' and 'structures of motivation' to create an 'ecology of participation' in installations. We describe how our first installation was used as a 'research vehicle' that guided and shaped the design of the museum installation. We also provide an account of how people interact with our installations and how this analysis has shaped their design. The paper closes with some general remarks about the challenges there are for the design of collaborative installations and the extent to which we have met them.

1. Introduction

In recent years, research in Computer Supported Cooperative Work (CSCW) has begun to include topics and settings which add to its traditional concern for the world of work and the information technologies to be found there. For example, Craven et al. [8] describe applications of collaborative virtual environments which have clear leisure and entertainment uses. While these authors speculate that the methods they have used for organising participation in game-like or story-telling environments might have applications in more traditional areas of CSCW (e.g. the coordination of contributions to a shared work task), this is not their primary concern. Mynatt et al. [19] discuss a community computing initiative called SeniorNet in which people who are or who are about to become retired from employment are supported in their use of networked computing technologies. Brown et al. [5] describe a system for music sharing (Music Buddy) which embeds this activity in social interaction and collaborative exchange. Again, the concern is to examine a phenomenon not normally associated with activity at the workplace to "learn lessons for more conventional CSCW applications" (p.180). All three of these examples demonstrate a growing tendency to broaden the remit of CSCW beyond workplace settings, systems and applications, even if an ultimate reference back to them is intended.

Another tendency in recent CSCW contributions is to examine the use of technology by a broad population of users. The Craven et al. research just mentioned is concerned to enable members of the public to participate in 'on-line experiences' of an entertaining kind. SeniorNet and Music Buddy are similarly broad in their conception as to who count as users of them (the over 50s, music fans). This stands in contrast to much traditional CSCW which trades on a strong conception of users or workers as engaged with particular work tasks and, through analysis of that work, offers design ideas or systems intended to mesh with those work settings. Rather, we see CSCW coming to engage with notions of 'the citizen' or 'the public'.

Indeed, some researchers have begun to examine people's encounters with technologies in public places such as museums and art galleries. Büscher et al. [6] describe a media art exhibition space and characterise the ways in which people move between the pieces contained therein, learn about them and cooperate with each other in making sense of them. On the basis of these observations, the authors make proposals for organising of large scale, interconnected multi-user virtual environments and enhancing their intelligibility. In recent work, Heath et al. [12] describe how people engaged, largely within small groups of friends, with an interactive visual installation so as to draw each others' attention to interesting features while cooperating on the joint operation of the piece. In particular, these authors are concerned with how co-participants shape each others' perception and appreciation of the installation, and how passers-by maintain a peripheral awareness of the activities of those directly engaged with it, perhaps learning from them when they in turn initiate interaction.

1.1 Social Scientific Design Sensitivities

The work we report in this paper is an extension of this emerging concern for engagement and collaborative interaction with technologies in public places in general and museums in particular. The paper centres on the design of two installations. The first, ToneTable, acted as a prototype and 'research vehicle' where we explored a number of interaction principles derived from social scientific design sensitivities. This research was then used to shape the design of a long-term installation, The Well of Inventions, at the Museum of Science and Technology in Stockholm, Sweden. Our work, in many respects, instantiates a design response to the social scientific precepts we gain from the work of Heath et al. and Büscher et al. and their studies of behaviour in public places with respect to artistic and museum pieces. In particular, we itemise two areas of concern we wish to be sensitive to in design.

- *Multiple forms of participation.* People manifest many different orientations towards artefacts, installations and exhibitions. There is a range of forms of engagement–central or peripheral, active or passive, overhearer/overseer etc.–which need to be taken account of. Visitors who are alone, and those who come with others, need equally to be accounted for. If possible, one should design so as to support the simultaneous coexistence of these multiple forms of participation in an 'ecology of participation' (Heath et al. [12]).
- *Interaction and co-participation.* Interaction should not refer to just the interaction of a single 'user' with an exhibit but should address the multiple ways in which people engage with each other in, around and through the artefact. This may involve providing "enhanced or variable functionality when participants interact with each other in and through the exhibit" (Heath, et al. [12]).

2. ToneTable

ToneTable is a multi-participatory, mixed media installation which embodies a number of systematic strategies for combining sonic and computer graphical materials in ways which support multi-participant interaction. The installation consists of a table-top graphical projection situated in the middle of a multi-speaker sound environment. We publicly exhibited ToneTable a number of times and continually refined its design in the light of experience, which allowed us to illustrate a number of interesting design principles in action in real practical settings. As we shall see, we have worked with some specific design concepts to respond to the social scientific sensitivities outlined above. As such, we hope our work shows how social scientific work in CSCW can be responded to methodically yet creatively.

2.1 Related Technologies

A number of table-top interaction devices with an embedded graphical display have been reported in the CSCW, HCI (human computer interaction) and allied literatures. For example, the InteracTable developed at GMD (http://www.darmstadt.gmd.de/ambiente/activities/interactable.html) uses a large projection onto a table top with information manipulation being supported by pen and finger-touch based interaction at a touch sensitive surface. Local infra-red networking allows other devices to be brought to the table for interaction purposes. Interactive sound has been incorporated into InteracTable to provide feedback to user gesture, in some cases through the physical modeling of dragging and writing sounds.

A further development of this concept is to combine the manipulation of specially designed physical objects on the surface with a projection of a computer graphical world onto the surface. For example, DigitalDesk [22] and phicons [16] are both concerned with the combination of computational media with a physical device or display surface.

Hoch et al. [14] describe The RoundTable in which a visualisation is projected up onto a table surface. On the table surface, a small number of phicons can be placed, which can have a variety of effects on the visualisation. The phicon positions, orientations and identities are extracted from video which is captured by a camera positioned above the table. Hoch et al. describe an application in which movements of the phicons control, amongst other things, the deployment and movements of virtual cameras in an on-line collaborative virtual environment, the table top visualisation providing a map-view of the overall environment. In an extension of this work, Bowers et al. [3] describe an application of The RoundTable in which the positioning of objects on the table surface mixes sound sources, a kind of 'mixed reality mixer desk'. The position, orientation and identity of objects in the visualisation denote sound sources, while the position et cetera of phicons placed on the surface denote virtual microphones with the mix at a selected virtual microphone being computed and rendered on a stereo loudspeaker system.

In our current work with ToneTable and The Well of Inventions, we decided to simplify the interaction methods to concentrate on design principles for supporting multiple participants working with sound and graphics. Accordingly, we chose to work with simple trackball based interaction (rather than the phicons and video processing of The RoundTable). This simplification enabled us to explore more satisfying inter-media relations than our earlier mixed reality mixer desk. Our installations support multi-user interaction with real-time sound synthesis, as well as sound file playback and processing, both in relation to the behaviour of a computer graphical animation.

2.2 Introducing ToneTable

ToneTable is a sound and computer graphics installation which enables up to four people to collaborate to explore a set of dynamical relationships between different forms of media [4]. We envisioned a scenario in which visitors would encounter a table within a room-sized environment which also contained a multi-speaker sound system. A visualisation of a real-time updated physical model of a fluid surface would be projected onto the table from above (Figure 1). The 'virtual fluid' would have its own autonomous flowing behaviour, as well as being influenced by the activity of the visitors. A small number of virtual objects would be floating on the surface, and these would move around the display in response to the dynamics of the modeled fluid surface. By using the trackballs, our visitors would be able to move sources of virtual 'wavefronts' around the display, which in turn would enable the visitors to 'push' the floating objects. If the local force upon a floating object exceeded a certain threshold, the object would suddenly exhibit a radically different behaviour. In our realisation of ToneTable, we chose to let this new behaviour consist of an orbiting motion around the display, which would gradually come to rest and resume the more gentle meandering behaviour characteristic of the objects moving as a result of the flowing surface alone.

Figure 1. The graphical projection of ToneTable. Each of the four 'wavefronts' is associated with the motion of a trackball. The 'stars' are the visual representation of the spatialised sound textures.

To achieve a mixed media installation, our scenario involved a number of correlations between the interactive computer graphics and the sound. Each floating object would have a specific sound texture associated with it. By carefully arranging a set of four speakers in the vicinity of the table, we would create a soundfield within which these sound textures could be heard. Furthermore, the sounds would be spatialised so that their visual representation on the table was spatially consistent with their heard-location in the soundfield.

2.3 Design Principles and Scenarios

ToneTable can be seen as an exploration of a number of principles for the design of interaction in mixed media artefacts, principles that are responsive to the design sensitivities emerging from the social scientific work touched on above. These principles include (from [4]):

Layers of Noticeability, Varieties of Behaviour, and Structures of Motivation. Our ToneTable scenario involved a variety of sonic and graphical behaviours which would be progressively revealed through visitor interaction (both individually and collectively) with the trackballs. This would give a 'structure of motivation' to the installation. That is, we intended to provide an 'in-built' incentive to explore the table and its varied behaviours and image-sound relations. Indeed, the dynamical behaviours of ToneTable were defined and calibrated with various non-linearities. Our intention here was to make the exploration of ToneTable an open-ended affair with some of the behaviours it is capable of being 'emergent' and not necessarily known to the designers in advance. As such, we were hoping that ToneTable would make for a contrast with interactive installations where there is a 'key' or hidden, underlying principle that needs discovery and, once discovered, exhausts the interest of the piece. Finally, by 'layering noticeability and interaction' in the manner we have described, we wanted to create an artefact which could be explored over various timescales. While there would be an immediate responsivity to its use, additional behaviours would be revealed with more extended engagement. In this way, ToneTable is intended to give value no matter how long visitors engage with it.

Interaction Through a Shared Virtual Medium and Emergent Collaborative Value. Our ToneTable scenario was developed to support interaction between visitors through a shared virtual medium. By coordinating their activity in that medium, visitors can engender 'added values'; behaviours of ToneTable which a person acting alone can not so easily obtain. However, the resting state of ToneTable would not be without interest and variety: it would have a variety of behaviours available to visitors acting alone. The intention here was to design an artefact which permits variable forms of engagement, both individual and collaborative, both 'hands-on' and spectating. In addition, by coordinating activity through a common virtual medium, we hoped that participants could gracefully move between one form of engagement and another. They could work individually or in close coordination with others through the use of the same devices and repertoire of gestures. Thus, collaboration would not require a switch of 'interface mode' over individual activity (cf. the proposals for 'encouraging collaboration' in [1]).

Variable Image-Sound-Activity Associations. ToneTable relates image, sound and participant-activity in a variety of ways. Sound is associated with individual graphic objects. Sound is also associated with individual device-usage. This variety of strategies was intended to enable an approach to the mixing of media which is rich and more satisfying for participants than if just one technique had been employed. It has the consequence that a single gesture may well produce multiple sonic effects.

Abstract, Yet Suggestive Content. ToneTable was developed in cooperation with the Museum of Science and Technology in Stockholm, a cooperation which carried over into the development The Well of Inventions. The museum allowed us autonomy in the design of content for The Well of Inventions, which enabled us to regard ToneTable as a 'research vehicle' for exploring various inter-media design strategies and approaches to collaborative interaction. These strategies and approaches then became the foundation from which the design of The Well of Inventions was built. The content of both installations is 'abstract, yet suggestive'. That is, neither installation attempts to compete with any of the museum's substantive exhibits. They both suggest the domain of fluid dynamics and could be related to other interactive exhibits whose treatment of physics is more 'correct' than our approximations. They do not directly attempt to teach fluid dynamics but could provide an occasion for a teacher or the museum staff to do so. By dealing with content in this way, we hoped to produce exhibits of a playful sort that could be incorporated alongside more pedagogical exhibits or be treated as just fun.

2.4 Observations of ToneTable in Use

ToneTable has been presented to the public on a number of occasions, and feedback from the public enabled us to refine its design (cf. [4] for details). In addition, we also collected video-based material at one of the public events where ToneTable was displayed. Although this material was not optimal for detailed interaction analysis (sound quality was poor, for example), we were able to use it to draw a number of conclusions that assisted in shaping the design of The Well of Inventions.

Our treatment of the data collected (video-recordings and field notes) draws upon principles of ethnographic research as established in CSCW by authors such as Hughes and his colleagues (e.g., [2]) while being sensitive to interactional phenomena of the sort documented by Heath et al. [12]. This social scientific tradition of research emphasises detailed descriptions of the data (here concerning interaction and gesture in relationship to a mixed media artefact) rather than a hypothesis testing approach.

In general, most of our visitors appeared to endorse the quality of sound and graphics in ToneTable, together with the existence of different behaviours which could be progressively uncovered. Some visitors, however, were less tolerant of something 'abstract, yet suggestive' and found ToneTable lacking in real content (an issue which we shall return to in section 4). However, amongst those who were willing to enter in a more playful spirit, we were able to see many examples of careful collaborative interaction between participants at the table as, on a number of occasions, people coordinated their gestures to jointly elicit the orbiting behaviour and other effects.

Gestural Variety. Although ToneTable used conventional trackball input devices, it should not be thought that there is necessarily anything lacking in them with respect to their usefulness in this setting. Indeed, we observed a great variety of different gesture types being performed on the trackballs, with correspondingly a variety of different behaviours being achievable in the virtual environment projected on the table and in the soundfield.

Some of the gesture types we have noted include the following.

- *Tickles.* By gently and in turn moving the fingers over the trackball a slow, continual, yet interruptible, trajectory of the wavefront across the table can be sustained.
- *Tremors.* By quickly moving a finger or the palm backwards and forwards or from side to side, the wavefront can 'shudder' on the display.
- *Rubbings.* By rolling the palm across the trackball, a large displacement of the wavefront on the table can be achieved. Such gestures have a characteristic acceleration and deceleration and a start-move-stop 'envelope'. They are often followed by a rubbing in the reverse direction as large oscillations across the display and the soundfield are accomplished.
- *Circular rubbings.* By rolling the palm around the trackball, a large continuous circular path can be inscribed on the display, perhaps pushing sound objects around the soundfield along the way.
- *Single finger rub.* A single finger, commonly the index, might be used to accurately and delicately position the wavefront at a particular locus in the display so as to interact with, for example, a single object/sound.
- *Flickings.* A single finger, again commonly the index, is withdrawn under the base of the thumb and out of contact with the trackball, it is then suddenly released, hitting the ball which turns freely and then decelerates while the flicking finger follows through. This produces a trajectory on the table with sudden onset and rapid movement, and a corresponding sudden change in the soundfield.

Coordinating Gestures. Our video recordings revealed a number of examples of co-participants closely coordinating the kinds of gestures they perform and their temporal patterning. For example, at one moment, Y initiates a rubbing gesture to perturb one 'corner' of the graphical display. Immediately following this, M moves his wavefront to the same corner and performs the same gesture type. After a couple of seconds of this joint activity, they both simultaneously 'expand' the rubbing behaviour so as to take in more of the display in their wavefront movements with a highly noticeable increase in intensity of the activity sonification accompanying their gestural expansion.

Figure 2. Coordinated gestures at the table.

Figure 2 shows three people at ToneTable. The two to the right of the picture are both jointly engaged in rubbing gestures, one with the middle and ring fingers in contact with the ball, one with the thumb. They are jointly achieving an extensive perturbation of the virtual surface at the corner between them. For her part, H with her back to the camera and to the left of the picture is rubbing the trackball vigorously with the palm of her hand, producing large movements of her wavefront over the rest of the display. At this moment, then, a pair of participants are coordinating their gestures with each other in close interaction, while a third person employs a gestural type which will enable her to make a big effect but without disturbing them. Importantly, then, the table is able to support the coexistence of a variety of gestural types and activities. It does not enforce all participants to collaborate with one another and is tolerant of variable groupings and foci for activity.

Gestures in Physical Space. So far we have discussed some of the different gestures which we have observed being made with respect to the trackballs and the different effects in the graphical and sonic environment they produce. We have also noted how participants coordinate their different gestures with each other. We will now consider some other kinds of gestures, in particular, those not made on or with the trackball. For example, at one moment, K points to a region of the display just adjacent to where L and M are making their wavefront movements, and he is using the shadow of his hand in the projection to precisely pick out a graphical object he would like his co-participants to try to perturb.

Gestures of this sort are often precisely timed so as to accomplish a kind of 'commentary' or 'suggestion' with respect to what is going on within the display, without disrupting it. Equally, activity on the table often accommodates such gestural commentaries and suggestions as they are being offered.

In Figure 3, H is making a large circular gesture with her right hand to draw attention to the orbiting of a sound around the room's soundfield. In this way, she picks out a particular consequence of her activity at the table and draws attention to the relationship between sound and graphics. This occurs just after the moment depicted in Figure 2 where H was dramatising the effect of large gestures. The table and her gestural activity with respect to it is enabling H to 'instruct' visitors to the installation in the graphical-sonic relationships it contains for her. Throughout all this, two other participants continue to explore the table with smaller gestures.


Figure 3. Gesturally 'animating' the moving sounds.

Coming and Going. Throughout our work on ToneTable, we have been designing not just for hands-on use of the devices at the table but for a participant's trajectory through the installation. Our design is very flexible in how it allows for 'comings and goings'. A single person can explore the table, as can a pair both working together or separately. While up to four people can be accommodated hands-on, they can pattern their activity very flexibly. Equally, there is space allowed for others to peripherally participate, perhaps waiting their turn while watching, or allowing a friend to have their turn.

The simplicity of the trackball as an interaction device and the fact that it requires no special 'tooling up' or instruction allows comings and goings at the table to be elegantly managed. A visitor can peripherally monitor the action at the table standing close to one of the participants. When that participant gives way, the new person can take over probably having already worked out the associations of particular trackballs to particular wavefronts and having observed a variety of behaviours and gestural types. Our design makes it easy for a newcomer to 'pick things up' where an earlier participant 'left off' and either extend the earlier person's explorations or try something new.

Collaboration and Emergent Effects. In several groups of participants we were able to observe a repeatable pattern of coordination which tended to elicit the orbiting behaviour of the graphical objects and their associated sounds. If two or more participants approach one of the floating objects together following approximately the same trajectory with their wavefronts passing over the object at approximately the same time, then the object is highly likely to start orbiting. By jointly pursuing the orbiting object, the participants are likely to get the object to orbit again once it stops. This strategy of 'co-chasing' one or more objects is likely to systematically elicit the orbiting behaviour and maintain it, if not continuously, then at least prominently. A number of groups of participants realised this and organised themselves to achieve this outcome. In particular, one pair of participants returned to ToneTable on a further occasion with an extra friend so as to more effectively chase the computer graphical objects around the projected display, and make the sounds move around the room.

3. The Well of Inventions

At the initiative of the Museum of Science and Technology in Stockholm, we evolved the design of ToneTable into a long-term, unattended museum installation–The Well of Inventions–which opened in May 2002 and is currently still on display. Let us now describe how the design sensitivities upon which ToneTable was developed have been carried over into the new installation.

Layers of Noticeability, Varieties of Behaviour, and Structures of Motivation. It is well established within museum research that visitors' prior motivation and expectations together with their current knowledge, beliefs and interests shape and influence the outcome of their visit (e.g., [7], [13], [15], [11]). Choice and control, and whether such choice is governed by intrinsic or extrinsic factors have also been shown to be important factors. For specific interactive activities, characteristics like clear goals, immediate unambiguous feedback, and levels of difficulty that are in balance with the visitor's abilities have been shown to be important features of successful exhibit designs [9].

With ToneTable and The Well of Inventions, we have attempted to be sensitive to this research by providing visitors with artefacts that can be used in multiple ways, and where new features are progressively revealed through extended use. At the same time, uncovering all of these layered features is not essential to the quality of the visitors' experience. Furthermore, our ToneTable observations suggested that the use of trackballs might be particularly suitable for The Well of Inventions; while they were straightforward to use for most visitors, they also afforded a large range of expressive and creative types of interaction. Indeed, many museum installations make use of trackballs, albeit more often as a replacement for on-screen cursor positioning devices like mice than as an integrated part of an exhibit.

Interaction Through a Shared Virtual Medium and Emergent Collaborative Value. Recent museum learning research suggests that the social circumstances and how people interact with each other at exhibits directly influence the success of their museum visit [11]. Thus, many museums are now showing an increasing sensitivity towards designing exhibitions that encourage discussion and collaboration between visitors and between visitors and staff. However, the physical design of many interactive exhibits still neglects to explicitly support multiple co-present visitors, and this is especially true for computer-based exhibits (e.g., [11], p. 191, [10], [18]).

The interaction principles embodied in ToneTable thus seemed particularly suitable for the museum setting. By supporting simultaneous input from multiple co-present users, ToneTable enabled–and indeed seemed to encourage–collaborative behaviour. By projecting onto a table, other forms of participation were made possible, ranging from passive observation to pointing and gesturing. The physical design of ToneTable also allowed for graceful turn taking.

Variable Image-Sound-Activity Associations. Different forms of multimedia have been used in museum exhibitions for a long time. Such technologies are typically straightforward in their use of inter-media connections, e.g., CD-ROM-based catalogues, kiosks and listening booths. At the same time, museums are currently facing fierce competition from other entertainment providers such as theme parks and movie complexes, which has resulted in an increasing interest in state-of-the-art technologies (ranging from IMAX-like theatres with interactive elements to personal, portable digital assistants). However, non-trivial forms of associations between image, sound and visitor activity in interactive museum exhibits are still relatively rare. Thus, in addition to acting as a ‘research vehicle’ for the exploration of a number of interaction principles as described above, ToneTable also embodied a number of design principles that have previously received limited attention within the museum domain – principles we sought to extend in The Well of Inventions.

3.1 The Design of The Well of Inventions

From our observations of ToneTable, we concluded that while its basic design supports and extends important features of the modern museum experience, its content, aesthetics and physical features would have to be further developed before it was suitable as a unsupervised long-term exhibition. Furthermore, the number of visitors to the Museum of Science and Technology can be very large at times. Therefore, our new installation had to support larger groups of co-present users than ToneTable. As a result, we envisioned a configuration of the architectural space that would make it possible to walk through the installation area without interrupting the activities at the table. The space would also contain a spectator platform from which it would be possible to overlook the installation, and a number of movable stools would allow visitors to sit down at the table. Figure 4 shows the ensuing layout of the installation.

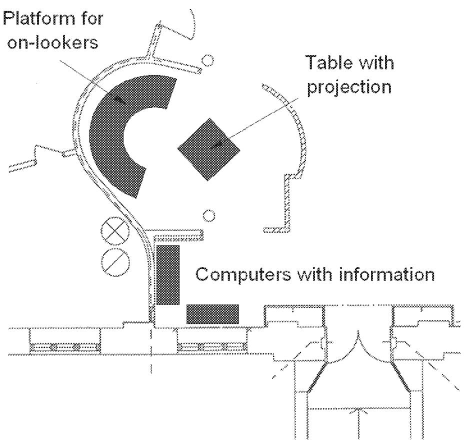

Figure 4. The layout of The Well of Inventions.

The Well of Inventions would be situated in the museum’s Science Centre gallery where most exhibits are of a concrete, pedagogically oriented, experimental nature. Thus, we felt that a more explicit content for our installation would be less disruptive and fit better with the general theme of the gallery. At the same time, we wanted to retain the overall ‘abstract, yet suggestive’ feel of ToneTable. The Museum of Science and Technology contains many artefacts that are associated with machinery and dynamics in different ways, and this provided us with a suitable theme for the installation. Thus, our scenario for The Well of Inventions involved replacing the abstract star-like floating objects of ToneTable with depictions of museum artefacts like propellers and turbines. The object sound textures were also modified to be suggestive of these depictions.

Our scenario also allowed the objects to be situated both above and beneath the fluid surface, and replaced the empirically developed equations that governed their motion in ToneTable with rigid body mechanics (Figure 5). We also extended the range of motion behaviours by replacing the original fluid-like animation of ToneTable with a two-dimensional fluid flow simulation beneath the water surface and an airflow simulation above the surface. As a result, trackball motion would ‘stir’ the water by injecting virtual forces into the simulation. Such 'stirring' would move the objects along the local velocity of the fluid flow. In addition, by correlating the buoyancy of the objects to their velocity, it would be possible to 'push' the objects through the water surface. Above the surface, the motion of the objects would be governed by the airflow simulation, which would allow them to move in a radically different manner. This feature would replace the original 'orbiting' behaviour in ToneTable. In our scenario, the trackball positions would also act as wind vortices that create turbulence in their vicinity. Thus, by coordinating their activities at the table, visitors would be able to collaborate to more readily push the objects through the water surface or cause the objects to 'hover' above the surface.

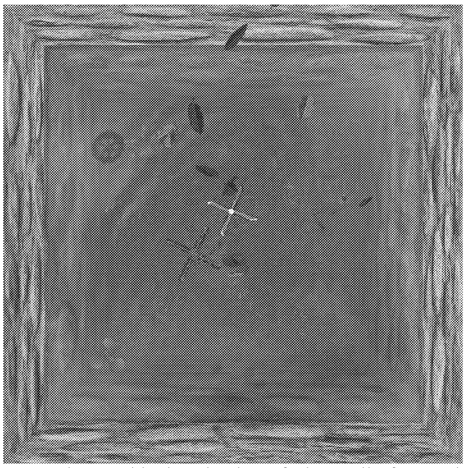

Figure 5. The graphical projection of The Well of Inventions.

While we acknowledged the need to provide visitors with background information concerning the purpose and goals of the exhibition, we did not want to introduce such texts into the main installation area. Thus, the installation was to be accompanied by an 'antechamber' that would contain a number of computer monitors. These monitors would display a set of different slideshows containing the background information.

Our scenario also introduced additional layers of noticeability, including ghostly reflections in the water and 'sticky' water. The reflections are images of machinery in which propellers and turbines are used, and constitute the inventions referred to by the title of the installation. 'Sticky' water is achieved by successively increasing the apparent viscosity of the fluid locally around two or more cursors when they are in close proximity for an extended period of time. When the cursors are brought apart, the viscosity gently relaxes back to its default value. In this way, the behaviour of the installation can subtly change depending on how visitors coordinate their movements and positions in the shared virtual medium. Further details concerning The Well of Inventions can be found in [20] and [21].

3.2 Observations of The Well of Inventions in Use

We have observed visitors interacting with The Well of Inventions for a total of approximately twelve hours, spread across multiple days. As with ToneTable, most of our visitors appeared to endorse the quality of sound and graphics present in the installation. Although our data indicate that visitors interacted with The Well of Inventions in ways that were similar to how visitors interacted with ToneTable, a number of interesting differences are also present.

Larger Variations in Dwell Times. Typical dwell times at The Well of Inventions varied from a few seconds to roughly ten minutes. The longest dwell time we observed was close to thirty minutes. Often, visitors would stay for at least a minute if they 'got hooked', which is considerably longer than with ToneTable.

Opportunities for Rest and Relaxation. The Well of Inventions appears to provide many visitors with an opportunity for relaxation and rest. On many occasions, we have observed visitors who approach the installation at a high pace and initiate their interaction with it through quick and aggressive trackball gestures, and then successively relax down into a slower pace and more intricate and careful trackball movements. Our observations also include other types of visitor body postures that are typical of restful environments, such as relaxation and lowering of shoulders, sighs, leaning forward towards the table, and using the table to support arms and body weight. The environment also seems to afford a more quiet verbal intercourse than other parts of the Science Centre.

Layers of Noticeability Were Challenging to Discover. Of those that interacted with the exhibition, about one in five discovered that it is possible to push the underwater objects through the water surface, while almost all ToneTable visitors were able to produce the orbiting behaviour. Most visitors that interacted with the exhibition were able to discover the association between trackballs and cursors (and reliably produce the splashing sound associated with high trackball activity). Those visitors that did manage to push objects through the surface frequently co-operated with others to keep them in the air. Only a small number of visitor groups discovered that the water surface has the ability to become 'sticky'.

Age Group Differences. As with ToneTable, it was common for one visitor to discover a feature and demonstrate to other visitors how to use it. However, our ToneTable visitors were almost exclusively adults, while visitors to the Museum of Science and Technology are a substantially less homogenous group, both with respect to age and demographic background. With ToneTable, visitors would sometimes leave to bring back friends, and this behaviour occurred at The Well of Inventions as well, especially among children. Young children were often fascinated by the graphical animation of the water surface and would put their fingers onto the display to 'feel' the water. Children in the approximate age-range of ten to thirteen seemed to be more interested in the exhibition than other age groups. These children typically viewed the exhibition as a game: they often (quite enthusiastically) referred to the transformation of objects moving through the water surface as 'a kill'. However, adults expressed less interest in the installation, and would often encourage their children to leave while they were still engaged at the table.

Interaction with Other Visitors. Many of the visitors that entered the space as a group discussed the purpose of the installation and the nature of the interaction. They also verbally negotiated the meaning and underlying rules of the motion of the objects. The issue of legibility was of limited concern with ToneTable since a member of the design team was always present within the installation to explain its background and purpose. With The Well of Inventions, the computer screens in the antechamber provide this information. During our observations, however, very few visitors read the text on the screens. Many adult visitors also expressed puzzlement with respect to the educational goals of the installation, which may account for the fact that many adults encouraged their children to turn to other exhibits in the Science Centre.

Figure 6. Interaction at The Well of Inventions, as seen from the antechamber. Note the person quietly observing the activities at the table from the platform in the background.

The Design of the Environment. Apart from the fact that a few visitors found it difficult to spot the trackballs that are built into the table, the environmental design of The Well of Inventions appears to be largely successful. Most visitors that enter the Science Centre gallery approach or walk through the installation, and it is able to support both observation and active participation simultaneously (Figure 6). Larger groups of visitors also make use of the platform for on-lookers (when space runs out at the table) and older children often spend extended amounts of time exploring the physical features of the room, such as determining the source of the graphical projection or searching for a hidden 'control room'.

4. Conclusions: Designing Mixed Media for Public Settings

In this paper, we have presented two installations which combine, in a number of different ways, high quality computer graphical and sonic materials in room-sized environments. We have exhibited these installations on numerous occasions, ranging from short demonstrations to long-term unsupervised display. We have adopted a design strategy of incremental improvement in the light of experience, while being guided by some substantive design principles and concepts. These have been proposed as responses to social scientific sensitivities emerging from studies of interaction with and around artefacts within public places. Overall, we believe that we have developed artefacts which support collaboration and which are tolerant of multiple coexisting forms of participation. This enables people to explore a variety of gestures and concomitant behaviours of graphical and sonic objects. The installations have been exhibited with systematic regard for the trajectories people follow as they participate in relation to the artefacts at different times and in varied relationship to other people. Furthermore, we believe that we have produced two engaging mixed media installations which are sensorially rich without being overwhelming, and which repay repeated visits.

However a number of challenges endure.

- *Educational issues.* Neither ToneTable nor The Well of Inventions has any elaborate high-level educational goals in themselves (although, as we have pointed out, they could be used by museum staff or teachers as tools in an educational context). However, our observations of The Well of Inventions indicate that some adult visitors encourage their children to leave the installation. We believe that one important reason for this is that the installation is situated in a Science Centre, where adult visitors can expect exhibits to feature a straightforward pedagogical 'opening' from which educational interactions with their children could be built. Because few visitors make use of the information available in the antechamber, this 'opening' is not readily apparent in The Well of Inventions. Thus, we are currently experimenting with different ways of subtly suggesting such 'openings' within the main installation area itself.

- *'True' collaborative emergence.* While we have referred to 'emergent collaborative value' as a strategy for giving motivation to collaboration, it is questionable whether our installations truly manifests 'emergence' in the stricter senses one often encounters in the literature on complexity and non-linear dynamics. To obtain a greater likelihood of novel and unexpected behaviour as participants interrelate their conduct, we simply introduced thresholds in the underlying dynamics. This has the virtue of the dynamics being manually 'tuneable': the threshold can be set to taste with ease. A more thought-through non-linear dynamics could allow for a greater variety of behaviours emerging with different constellations of participants. In addition, a time-varying dynamics (e.g. possibly through the mutation of the underlying dynamical equations or a drift in their parameterisation) would allow for yet further behaviours to be encountered on re-visiting. Such dynamical systems would require a kind of 'in-line' calibration of their equations to user-input. This is a difficult, yet fascinating challenge.
- *Object-sound associations.* Some of the sounds in play in ToneTable and The Well of Inventions stand in a one-to-one relationship with particular graphical objects. However, even with a small number of sound-object pairings (currently four), we do not have evidence of participants commonly 'decoding' the relationships so that they can, say, 'map' the rattling sound to the brown aircraft propeller. It has to be noted that participants were not set this as any kind of 'task' to perform but neither did these particular object-sound relations form part of their spontaneous discourse at the table. Other sound-image-interaction relations were clear as intended, however. For example, the sonification of activity at the table was clearly notable in both ToneTable and The Well of Inventions and, even, 'performable/playable'. A number of visitors have compared the installations to, or could imagine an extension of them, as collaborative musical instruments.

Let us finish this account by drawing out some lessons of general interest from our design work and our studies of people interacting with ToneTable and The Well of Inventions.

When interactive artefacts are deployed in public settings, it is noticeable that people take very varied orientations to interaction with them. An important challenge is to think how these multiple and varied participation formats can be designed for in an integrated fashion when developing an artefact (installation, exhibit or whatever) for a public setting. This is a much more complex question than those traditionally discussed in HCI research under the rubric of 'usability', and points beyond 'interface design' narrowly considered to the careful design of all environmental elements: computational, architectural and social. In our development of ToneTable and The Well of Inventions, we have tried a number of design strategies for addressing such settings. We have explored notions of 'collaboration through a virtual medium', 'emergent collaborative value', 'layers of noticeability', and 'structures of motivation'. Other important issues concern ergonomic aspects, social interaction, age group differences and affordances of the overall physical environment. These are all concepts and sensitivities intended to suggest ways for orienting the design of mixed media artefacts to support variable participation in public settings.

Acknowledgements

Initial steps developing ToneTable were taken during a 'constructional workshop' of the EU's IST project SHAPE (http://www.shape-dc.org), part of the Disappearing Computer initiative. We thank all our SHAPE colleagues for their participation at that workshop and support in the subsequent development and study of ToneTable. We would also like to thank the Museum of Science and Technology for hosting The Well of Inventions and for the helpful participation of the museum's staff. The support of Clavia DMI is also acknowledged.

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Paper F

Taxén, G., and Frécon, E. The Extended Museum Visit: Documenting and Exhibiting Post-visit Learning Experiences. In Trant, J. and Bearman, D. (eds.). *Museums and the Web 2005: Proceedings*, Toronto: Archives & Museum Informatics. CD-ROM Proceedings.

Paper F

The Extended Museum Visit – Documenting and Exhibiting Post-Visit Experiences

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ABSTRACT

During the last couple of decades, a growing body of research has provided insights into the complex processes of learning that take place in museums. Interestingly, museum-related learning is not limited to the actual visit - what takes place before and afterwards has a profound effect on the learning outcome. The study presented in this paper focuses on the post-visit aspects of the learning process.

Previous research shows that visitors make connections between their experiences in the museum and experiences that happen after the visit. Sometimes, these connections can occur weeks or months (or even years) after the visit, depending on when the visitor happens upon a situation that allows the connection to be made.

Documenting these events is obviously quite difficult. Even though it is possible to re-establish contact with visitors after a few weeks or months (e.g., through telephone or e-mail), the information one obtains is not *in situ*. The goal of the present study is to attempt to acquire and analyze more data from these *in situ* situations, and to re-present the data in an exhibition. To this end, we have designed a system that allows visitors to send images and text messages to a central server through e-mail, SMS or MMS. The data from the server can then be visualized as a weblog (blog) or in some other suitable form.

We collaborate with the Museum of Science and Technology in Stockholm, Sweden. A large part of the Museum's Science Centre is devoted to five mechanic principles: the screw, the plane slope, the lever, the wheel and the wedge. We have designed an exhibit that utilizes our system to present messages (images and text) from visitors on the subject of the five principles in the science centre itself. It is also possible to access the messages through a public webpage.

Proceedings of Museums and the Web 200, Toronto: Archives & Museum Informatics. Published on-line at http://www.archimuse.com/mw2005/papers/taxen/

From the Museum's perspective, our exhibit does not only provide new opportunities for documenting post-visit learning processes, but also has the potential to provide new forms of evaluation data that might be difficult to obtain through other means. Furthermore, it allows the Museum's visitors to extend the original scope of the mechanical principles exhibition by allowing them to provide their own content (and reflections upon the existing content), which is a re-occurring theme in many recent technology-based exhibits.

The paper provides a description of our system, the exhibit we have built, how the exhibit is managed, and a description of how it has worked in practice.

Keywords

Learning, Visitor contributions, Post-visit experiences, Design

LEARNING IN MUSEUMS

It is not uncommon for museums today to be involved in different forms of educational activities, and the museum is often regarded as an important tool for educating the public. However, the nature of the learning that takes place in the museum has been the focus of both research and numerous debates during the last few decades.

A common late nineteenth century conceptualization of museum object representation was that any given object could be seen as a representative of its class. When designing displays, there was no room for ambiguity regarding the meaning of any given object (Bennett, 1995, pp. 42-43). In other words, the objects themselves and the way they were arranged were seen as having the capability of communicating a certain, specific meaning to the visitor. This view of learning appears to have been very influential until quite recently (e.g., Hooper-Greenhill, 1994) and indeed, the notion of meaning as something encoded in the design of an exhibition has been embodied within numerous communication models for museums since the 1970s (ibid.). A common assumption in these models is that the visitor can later decode the message that has been encoded into an exhibition or exhibit by the designer. When this decoding does not take place (or when it becomes erroneous), it is considered to be the result of different kinds of interference, both with respect to the exhibition itself (e.g., signs may have such a small font that they become difficult to read) or with respect to other visitors (e.g., another visitor moved in front of a sign as it was being read).

However, such models of interpretation have recently been criticized by researchers that argue that more holistic perspectives are required. More specifically, it is claimed that museum visitors should be thought of as active interpreters rather than as passive message decoders – their background, previous experiences, current wishes, expectations and motivation towards the subject at the time of the visit are factors that heavily influence the learning outcome (e.g., Hooper-Greenhill, 1994, Caulton, 1996, Hein, 1998). In addition, learning does not only depend on the interplay between the exhibition and the visitor – other physical and social circumstances of the visit also shape the learning process to a large extent (Falk & Dierking, 2000). So rather than focusing on the exhibition as embodying a specific message (encoded by the exhibition designer), these authors instead tend to focus on the museum visitor as a unique individual who creates individualized meaning from the exhibit by way of the interplay between the personal, social and physical circumstances of the visit.

Interestingly, the learning process does not appear to end when visitors leave the museum – in fact, it seems that many people continue to construct new knowledge from their visit for long periods of time. Indeed, it seems that many people draw conclusions that are related to their visit *outside* the museum, after the visit, when they encounter a situation that allows them to "make a connection" (ibid., pp. 4-10). Documenting these situations is, naturally, quite difficult. Falk and Dierking mention a number of studies where researchers have telephoned visitors some time after the visit and asked them to recall the museum visit and how it has shaped later encounters and experiences. Although important and valid, this data consists of the learners' recollection of their experiences and there is typically no "hard" data from the actual situation itself (e.g., video or tape recordings). Thus, one of the goals of the study presented in this paper was to see whether it was possible to obtain such *in situ* data through the help of modern communication technology.

We work with the Museum of Science and Technology in Stockholm. The specific target of our study is a collection of exhibits in the museum's science center called the "Mighty Five". These exhibits illustrate five mechanical principles: the screw, the plane slope, the lever, the wheel and the wedge. The museum has been planning a re-design of its science center for some time, and is currently evaluating the exhibits. Thus, our work had the opportunity to provide data that might support the evaluation process. One of the early results of the evaluation is that many visitors fail to grasp the way the exhibits relate to one another (i.e., that they constitute a set of different, yet interrelated mechanical principles). By exhibiting examples of situations when the "Mighty Five" have been discovered outside the museum, we hoped that we would be able to provide an additional context for supporting the conceptual integration of the exhibits in the room.

EXHIBIT DESCRIPTION

Our work began with a pre-study where we developed the initial idea for our exhibit: a sort of logbook where visitors could record their museum-related experiences through cell phone SMS and MMS messaging. The reason for focusing on SMS messages was that cell phones are ubiquitous devices today: most people (even rather young children) own one, or have constant access to one. It is a device that most people find natural and easy to use, and SMS messaging is a well-known and popular communication feature. Mobile telephones with cameras and multimedia messaging capabilities are also becoming rather common, which would provide an additional data channel for our visitor contributions as well.

In order to judge the feasibility for such an exhibit, we began by interviewing a small number of students and adults. The questions were very open-ended, but mainly focused on the issue of motivation, i.e., what would be enough to motivate a person to send an SMS message to a museum exhibit? The answers indicated that for some people, the ability to shape an exhibition in a museum and have other people read one's opinions in the museum would be enough. For other people, some sort of competition or explicit task was felt to be required. We also looked at other similar applications that appeared to be successful. For example, *City*, a free newspaper published in the Stockholm area, features a daily SMS-chat column to which anyone can contribute: with a bit of luck, the message will appear in print next morning. These initial investigations suggested that it might be worthwhile to develop a prototype exhibit.

Our first design consisted of a large white book onto which text was projected using a computer projector. By pushing at the edges of the book, it was possible to "turn the page". Each "chapter" in the book corresponded to one of the "Mighty Five". The chapter selection was done by placing one of five prepared phicons (physical icons) (Ishii & Ullmer, 1997), each corresponding to one of the "Mighty Five", onto a RFID tag reader. The book had the capability of receiving SMS, MMS and (for completeness) e-mail messages, and each new message was added as a paragraph in the book. A "live" copy of the book could also be accessed from the WWW.

The prototype was exhibited at two public events: the first was at the annual Open House at the Swedish Institute of Computer Science and the second was at a project evaluation event at the Stockholm Concert Hall. We estimate that roughly 150 visitors used the prototype during these two events. The outcome of the first event was encouraging, although it became obvious that the user interface for page-turning was quite awkward in practice.

As a result, we chose a new metaphor for the exhibit – that of a book roll – and the page turning interface was replaced by a handle for "rolling" the book roll text forwards and backwards. The new prototype was received favorably at the second event, and the new handle-based interface seemed to work well. Thus, we decided to build a version suitable for exhibition.

The resulting exhibit is designed as follows. The core of the exhibit is an off-the-shelf weblog (blog) installation (currently WordPress, http://wordpress.org/) with two different output channels. Apart from being available as a website as any other blog, the blog is also visualized differently in the museum. The exhibit itself is designed to suggest a magic book roll on which visitors can read the messages currently available (figure 1). Each message is drawn in a hand-written style and can also contain any number of pictures (figure 2). The messages are also marked with the date and time of their arrival. A wooden lever can be turned to scroll through the book. One chapter at a time is shown and changing chapters is done by placing a wooden phicon on top of a large circular target (figure 3). The phicons have shapes that are intended to be reminiscent of the "Mighty Five" and are color coded. The visuals are projected from above using a computer projector, which gives the book an attractive surface glow. Because the exhibit makes use of RFID tags, the phicons do not have any visible wires or buttons, which we felt might contribute to the overall feeling of magic that we wanted to achieve. The design of the Web site attempts to offer enough cues so as to connect the site back to the exhibit (figure 4): hand-written titles, icons that resemble the wooden phicons and with the same color codes, etc.

Figure 1. Our book roll exhibit.

A poster and a stand with pocket-sized explanatory leaflets are positioned next to the exhibit. They illustrate how messages arrive at the book and also describe how visitors can contribute with their own content. The leaflet also lists the relevant phone numbers and email addresses, and provides the URL for the WWW version of the book. The user interface of the exhibit consists of two input devices. The first is an optical USB mouse that is hidden in the right-hand-side of the book roll. When the lever is turned, the mouse registers the motion as mouse pointer movement, which is used to determine how much to move the book text. The second input device is a RFID tag reader which is hidden under the front side of the table on which the roll is positioned. This device recognizes RFID tags that have been embedded into the five wooden phicons. Whenever the tag reader status changes, a report is sent to the visualization system which, in turn, changes the book chapter accordingly.

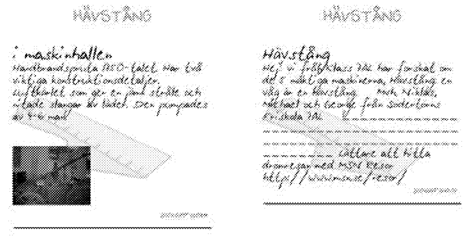

Figure 2. Example messages (with images) in the book roll exhibit.

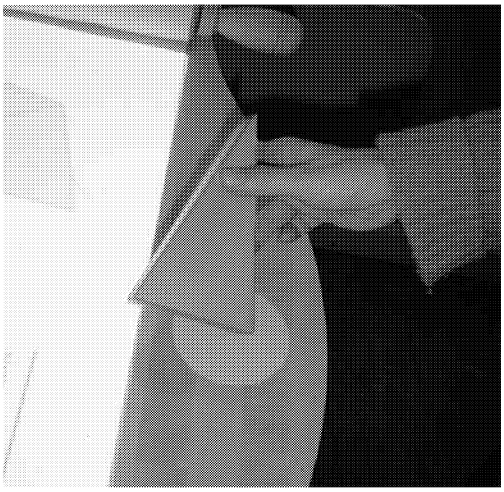

Figure 3. Wooden phicons are used for book chapter selection.

The same phone number is used for SMS and MMS contributions. Chapter differentiation is made by using the first word of the message or the subject header (which is assumed to correspond to the name of one of the five mechanic principles). Extended SMS messages (i.e., longer than 160 characters) are accepted. For e-mail contributions there is one specific address for each of the "Mighty Five". MMS messages and e-mails may also contain pictures. Currently, all content is sent to the blog without moderation, although current web technologies would make it a simple task to supervise new entries: once an inappropriate message has been discovered by the museum staff, it can immediately be removed using any standard web browser.

Figure 4. A snapshot of the main Web site on the 28th of January 2005.

From a technical point of view, the core of our exhibit is mBlog, a system for mobile blogging being developed at the Swedish Institute of Computer Science (Frécon, 2003), together with a set of programs for the supervision of overall system behavior. There are a number of existing solutions for so-called moblogging, i.e. the ability to send content to a blog from mobile terminals. For example, NewBay Software markets FoneBlog (http://www.newbay.com/) to mobile operators, and a number of blogging systems have an e-mail input interface, including TypePad/MovableType (http://www.movabletype.org/) and WordPress (http://wordpress.org/). Our system, however, differentiates itself through a very flexible architecture and its ability to adapt to any blogging back-end that supports the XMLRPC API (Winer, 2002). The system associates one separate operating system process to each core task that it has to perform. There is, for example, one process for SMS reception, one for the transformation of SMS into blog entries, one for e-mail reception, one for the transformation of e-mail messages into blog entries, and so on. A text based communication protocol, with a separate set of commands for each process, is used. This simplifies remote maintenance and allows the system to be run across multiple computers for efficiency. All client-server connections have a basic level of security that is based on the allowance or denial of connecting hosts.

For robustness, the system has several self-monitoring technical solutions with a number of error recovery capabilities. These solutions also produce reports when something does not work as intended. Connections between processes are kept alive on a continuous basis: as soon as a client discovers that a server has disappeared, it will start to periodically attempt to reconnect until it succeeds. Also, a special supervision process manages all processes that are part of the system. This supervision process ensures that the other processes restart in case of error and also provides a common context of execution, which provides the ability for text-file logging and resource management. The system also provides a number of commands for remote operation: manually restarting processes, polling for their presence, forwarding their currently logged output, etc. Furthermore, the system operator is automatically warned through e-mail if any run-time errors or failures occur.

Data integrity is another key aspect of the mBlog system. All processes that accept input from other devices or processes work using spoolers. Once received, the data is immediately copied to the "inbox" spooler area. Each process separately monitors this area and manipulated data is copied to the "outbox" or "error" spooler area. Data recovery is then a matter of copying a file from the appropriate directory. Furthermore, all process activity is extensively logged, database backups are done at a regular basis and the log of the behavior of the processes at the museum exhibit is dynamically copied back to our local network, which allows analysis of, e.g., user interface usage.

Figure 5. Surroundings of the book roll exhibit at the Museum of Science and Technology in Stockholm.

Our museum exhibit was assigned a location directly to the left of the entrance to the room containing the "Mighty Five" exhibition, underneath an existing poster that outlines the contents of the room (figure 5). To the right of our exhibit are a classic blocks-and-tackles exhibit and a larger exhibit that is intended to illustrate the principle of the screw. To the left, directly in front of the entrance, is an exhibit featuring a number of interconnecting cogs of different shapes. In the center of the room is a partly enclosed area with different toys, slides, and smaller exhibits, and the rest of the room is devoted to larger exhibits, most related to the "Mighty Five".

In order to "get the ball rolling", we wrote a number of messages for each of the five categories ourselves (e.g., "here is a sort of lever" together with an image of a playground see-saw or "a playground slide is a form of plane slope"). We then left the exhibit alone for a couple of weeks (with the exception of correcting a few technical issues that arose early on). Our first authentic message appeared after approximately one week: "Hello! We from class 7AL have done research on the Mighty Five. Lever: a pair of scales is a lever. Cheers from Niklas, Michael and George." This was very encouraging, but unfortunately no further messages appeared, so we decided to observe visitor behavior at the exhibit.

OBSERVATIONS

We observed visitors in the science center for a total of approximately five hours spread over two days, and recorded our observations as notes and still images (unfortunately, no video or audio recordings were allowed – it is against the museum's privacy policy).

The science center audience is quite heterogeneous. Most visitors are children and appear to be between 2 and 18 years old, and normally one or several adults accompany the children. The younger children almost exclusively devote themselves to the "playground" in the center of the room and very few paid our exhibit any notice. Older children and adults typically discovered our exhibit on their way to or from the blocks-and-tackles or screw exhibits, but we estimate that it was overlooked by roughly 30-40% of the visitors that went by. It was more common for adults to take note of our exhibit than children, and this often happened when they were waiting for their children to finish examining one of the other nearby exhibits.

Of those that did interact with our exhibit, most seemed to investigate the workings of the user interface (i.e., tried to put the different category blocks at different locations on the exhibit to see what would happen). A common tactic was to place the blocks onto the projection itself (where the corresponding shapes are drawn), which unfortunately do not achieve anything. Some tried to turn the handle before positioning one of the blocks on the tag reader, which also have no direct visual effect. Consequently, we have marked the active elements of the user interface more clearly with red color, which appears to have had a positive effect. Of those visitors that did open a chapter in the book, a minority seemed to actually read the content. Also, few visitors seemed to read the poster or the leaflets. Indeed, very few visitors seemed to read any of the written texts that appear elsewhere in the room. We are currently experimenting with different ways of adding non-textual usage instructions (e.g., cartoons) into the book itself.

On a more positive note, we have evidence that for those visitors that do read the messages, our exhibit has the potential to support the other exhibits in the room. For example, the images below shows a woman and a girl that, after some experimentation, managed to position a phicon onto the tag reader to uncover one of the message categories. They then went on to read the messages together (figure 6). During this activity identified and pointed to exhibits in the room that corresponded to the different messages she and her companion discovered in the book (figure 7). Thus, our exhibit allowed the two visitors to connect the other exhibits to everyday objects and machinery in the "real world", which suggests that our exhibit has the potential to provide a more substantial context for the exhibits in the science center than what was available previously.

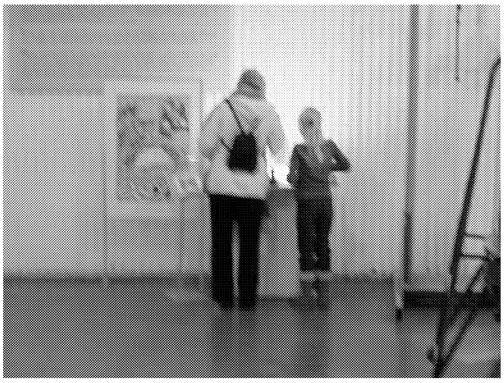

Figure 6. Visitors reading messages in the book roll exhibit.

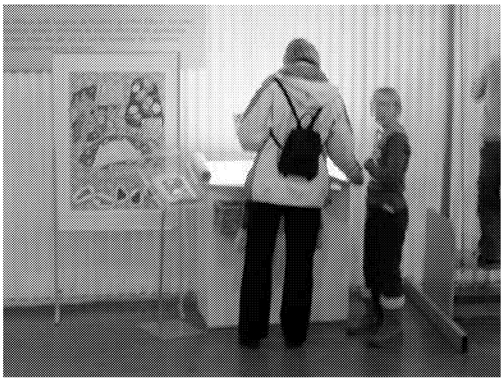

Figure 7. Pointing out exhibits corresponding to messages in the book roll exhibit.

DEALING WITH THE LACK OF CONTRIBUTIONS

Based on the results of the pre-study, we had prepared for the possibility of not receiving any messages to analyze by arranging for a contest as an additional motivation. Since no new messages appeared, we announced that we would distribute 10 movie tickets among the contributions that arrived during a week-long period in connection with the Christmas school holiday. A sign that informed visitors of the competition was added to the exhibit. We also visited the museum in person, explaining the exhibit to visitors and encouraging them to contribute. The response was very favorable with regards to the exhibit itself and its core ideas, but unfortunately, no further visitor contributions appeared.

We always knew that there was a definite possibility that no messages would arrive, but the poor outcome of the contest was nevertheless rather surprising. At the time of writing, we have no data to support an analysis of why visitors chose not to contribute, but we speculate that the reasons may include the following.

- Not a single mischievous message has appeared (apart from a small number of automated spam e-mails), which suggests that it may be hard for the visitors to understand that it is possible to actively contribute to our exhibit. Contributing requires reading instructions, either on the poster (or leaflets), or on the exhibit itself, and therefore our exhibit suffers from the phenomenon that text in general seems to be ignored in the "Mighty Five" room.
- It appears that visitors tend to treat the "Mighty Five" room as a "playground" with pedagogical opportunities rather than as a room for learning. A minority of the adults we observed took the opportunity to explain the principles represented by the different exhibits in the room to their children. Rather, they would focus on the practicalities of the exhibits (e.g., helping the children work a lever or tell them which button to push).
- Our exhibit appears to be difficult to notice in its current location.
- Our target audience is slightly older than the majority of children that visit the science center.
- Although many of the children and adults we spoke to at the museum were quite enthusiastic about a "Mighty Five treasure hunt" outside the museum, none actually went through with the activity. It may be that for many people, the museum visit ends when they leave the building, (i.e., it has no conscious post-visit phase where the experiences of the visit are developed and elaborated upon). Even if a situation is recognized as a museum-related learning experience, it may be difficult to remember our exhibit (not to mention finding the leaflet with the instructions for contributing). Or it may simply be that the opportunity to win a movie ticket does not constitute enough motivation for contributing.

In summary, we have had to draw the conclusion that for our given context, obtaining visitor contributions in the manner we intended is very difficult indeed. Consequently, we have decided to focus on other forms of contributions, such as engaging school classes in task-based activities. The first activity we initiated was a "treasure hunt" activity that involved two 6th grade school classes (12 year olds) with 27 and 10 children, respectively.

The activity itself was designed and hosted by a member of the museum's educational staff, and it began in the science center's multimedia theatre, where (after a short introduction) the "Mighty Five" was presented using a large notepad and models. Then, the children were divided into five groups (one for each of the "Mighty") and were asked to find an example in the museum's machine hall, which is a large area in the vicinity of the science center that contains numerous machines and machine components, engines, vehicles and models. Each group was also given a small notepad for writing something about their find. The groups then searched for roughly 20 minutes (the museum staff member and the teachers were present throughout to assist when necessary). When a group had found an example, they were given a digital camera and were asked to record their find. When all groups were done, we collected the notepads and asked the children to go back to the science center to examine the "Mighty Five" exhibits there. Meanwhile, we e-mailed the children's notes and pictures to our book roll exhibit, and notified the children when all messages had appeared.

It appears that the activity was largely successful: the children seemed to enjoy the "hunt" and both teachers and museum personnel were satisfied. Indeed, the teachers expressed an interest in continuing the activity in school (including reporting new sightings to the book roll) and the museum has asked us to extend the time our exhibit is on display so that they can design a new pedagogical program around it.

It should be noted that most of the children had not heard of mechanical principles such as those represented by the "Mighty Five" before, although of course the wheel and the screw were familiar to everyone. This means that for this age group, the pedagogical potential of the activity largely involved allowing the children to discover the ubiquitousness of the "Mighty Five". By drawing attention towards fundamental and common mechanical principles, it may be possible to lay the foundation for an increased motivation for learning more about how they work. In such a context, our exhibit has the potential to become a growing collection of "sightings" that illustrate how frequently the mechanical principles presented in the science center appear in everyday life.

Although we did not obtain enough data to analyze the learning outcome of the "treasure hunt" activity (we had originally intended to use Grounded Theory (e.g., Strauss & Corbin, 1998) as a method for organizing and analyzing visitor contributions), the 10 messages we did receive are nevertheless quite interesting. The texts can be divided into 5 categories:

1. Texts that copy the label of the exhibit corresponding to the find, in part or in whole (4 messages).
2. Texts that motivate why the image in the message constitutes a find (2 messages).
3. Texts that, in a single word, describe the type of machinery shown in the image (2 messages).
4. Texts that explain how the mechanical principle represented by the find works in this particular case (1 message).
5. No text at all (1 message).

The images associated with the texts contains either a depiction of the group's find (8 messages), or a depiction of the group itself in front of (or behind) their find (2 messages).

In our interpretation, the messages illustrate how the children are about to take the step from being able to recognize and name simple mechanical principles to also being able to describe how they work. The fact that two groups decided to depict themselves in their images is also interesting. The children were quite enthusiastic in general about being able to contribute to a real museum exhibit and, not surprisingly, being able to see a depiction of oneself in the exhibit supported and strengthened this enthusiasm. We interpret this as a partial confirmation of one of the conclusions we drew in our pre-study: that, as a visitor, being able to shape and influence a museum exhibit can be a motivating factor for contributing content.

CONCLUSIONS AND FUTURE WORK

On the one hand, it seems clear that for our given context, it is very difficult – if not impossible – to motivate visitors to contribute with SMS/MMS/e-mail messages outside the museum in the way we intended, unless they agree to do this as part of a special activity of some sort. The reasons for this are probably numerous. We have already identified a number of problematic issues with the design and placement of our exhibit, which we have begun to address. However, even if a museum-related learning situation is recognized as such by a visitor outside the museum, there is probably no real motivation for bothering with picking up the cell phone, finding the leaflet and sending a message. However, other forms of obtaining *in situ* data, such as cultural probes (Gaver & Dunne, 1999) and technology probes (Hutchinson et al., 2003) have been very successful in other contexts, and adopting them for the museum learning context may be a suitable topic for a future study.

On the other hand, our exhibit clearly has pedagogical benefits for the museum. We have evidence that it has the potential to offer a "real life" context for the mechanical principles presented in the science center, and the exhibit appears to be very useful as a target for pedagogical activities within the museum. We intend to continue to work with the museum to develop new activities that involve our exhibit.

Furthermore, the mBlog system has worked very well in practice and we envision numerous other museum-related applications with our system as a key component. One idea is to add a "Q and A station" to key exhibits in the museum, where visitors could submit questions related to the exhibit and receive answers from museum experts, either directly at the station or later (through SMS, e-mail, or the WWW). Previously asked questions (and answers) could be accessed in a similar way as in our book roll exhibit.

Finally, we hope that our experiment serves as an illustration of the fact that non-standard forms of exhibits and exhibitions may require iterative design *in place*, after they have officially been opened to the public. Even if pre-studies and prototypes show that such exhibits may be feasible, it may be necessary to modify (or even replace) parts of them while on display. In situations like these, it may also help to involve visitor representatives directly in the design process (Taxén, 2004, Taxén et al., 2003).

ACKNOWLEDGMENTS

This research is supported by DAPHNE, a project funded by the Swedish Foundation for Strategic Research. We would like to thank Mariana Back and Åsa Egeld at the Museum of Science and Technology and the two school classes for their participation. We would also like to thank the other DAPHNE participants for their contributions and suggestions.

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