# Dressing up for School Work– Supporting a Collaborative Environment with Heterogeneous Technologies

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**Abstract.** This paper approaches heterogeneity and heterogeneous technology as assets, rather than limitations, in the development of computer supported cooperative work. We demonstrate how heterogeneous technologies sustain teachers' and students' school work by presenting four different prototypes (the HyConExplorer, the eCell, the iGameFloor and the eBag) that complement one another because they offer different functionalities and are, at the same time, designed with the wholeness of school activities, particularly group-based ones, in mind. Thus, they provide teachers and students with a broad range of IT support to aid them in and outside of the classroom. We take the school domain as our point of departure, but argue that the focus on heterogeneous technologies is applicable for the general area of CSCW.

## Introduction

The scope of heterogeneity and heterogeneous technologies is vast within the field of CSCW. Many research contributions focus on heterogeneity as it is present between the different groups of actors in an organisation, for example within healthcare (see Bossen, 2002, Færgemann et al., 2005, Reddy et al., 2001), and describe possible solutions for the design of technology that may accommodate the disparate groups. Other studies of cooperative work within organisations have focused on the organisational aspects and work-arounds found when people are forced to juggle a number of heterogeneous applications and systems to get their work done; for example Bødker et al. (2003) describe work to which heterogeneity is a hindrance, because the technology in use is very poorly integrated, and thus 'heterogeneous technologies' becomes synonymous with 'devices and applications that do not work well together, if at all'.

With this paper, we approach heterogeneity and heterogeneous technology as assets rather than limitations. A common problem encountered when dealing with heterogeneity in technology design is the challenge of combining technology designed with different purposes and disparate design strategies, and this is what the term heterogeneity most often conveys. However, with this paper we want to present a new view on heterogeneity that lets us design with the disparate hardware and software capabilities in mind. In this sense we align our work with that of Fraser et al. (2003), who aim to "provide assemblies of artefacts to support a coherent experience.." (p. 181) when designing technology for museum visitors.

Our point of departure is collaborative activities, primarily project work, in Danish elementary schools, but even though the examples we present originate in a school context, the ramifications of designing *for* heterogeneity are applicable to CSCW in general.

We align ourselves with the work of Rist (1999) and Correa & Marsic (2005), among others, who are concerned with providing access to shared resources through a variety of heterogeneous devices in a way that takes advantage of the individual device and its capabilities (and recognises its limitations). However, the scope of group work in elementary schools, as described below, transcends the needs for accessing a collection of materials, and focuses on providing means for gathering, producing, assessing and presenting material in the course of a group project. We see a strong resemblance between our approach to heterogeneous technology, and the work by Anderson et al. (2000), who present the Chimera hypermedia system. This system allows programmers to use the tools to which they are most accustomed, and provides a variety of views of the same material to support the heterogeneity inherent in software development environments, thus allowing the programmers to choose the tool they find best suited to the task at hand or their particular style of programming.

In this paper we present four prototypes based on heterogeneous technologies that meet current educational challenges and provide teachers and students with new, flexible tools for engaging in the variety of different activities they encounter at school, and particularly in group-based project work: the HyConExplorer, the eCell, the iGameFloor and the eBag. The prototypes presented here are effective *because* they are heterogeneous rather than *despite* their heterogeneity; they complement one another because they offer different functionalities, and because they are, at the same time, integratable and designed with the wholeness of school activities, particularly group-based ones, in mind. These prototypes are but a few of the possible examples of novel IT concepts that can be introduced, and coexist with the ‘common’ types of technology we find in schools, for example PC’s, SMARTboards™ and laptops, and should be seen as an enhancement rather than a replacement of the already existing technologies. Together, they present a *medium* for collaboration rather than a *mechanism* (Bentley & Dourish, 1995); a flexible framework within which teachers and students can work and add content in accordance with the current topic, learning style and curriculum, and thus choose the right tool to ’dress up’ for school work.

# School work

The Danish elementary school system is changing, as new educational visions are gaining ground and shaping pedagogical strategies and practice, and technological advances introduce new tools for learning. The Danish Ministry of Education set out, in their vision for learning in elementary schools in the year 2010, a number of skills they consider important for the students to acquire, for example, learning to navigate increasingly heterogeneous sources of information, collaboration and fellowship, participation and responsibility, and problem solving and knowledge sharing (Undervisningsministeriet, 2000); the overall aim being to give students the right tools for entering a work force where *innovation* is becoming an important quality sought by employers. In this context, teachers’ and students’ roles are changing: Teachers are no longer lecturers but coaches; students are no longer passive recipients of information from a single source, but active, knowledge-producing actors who need to juggle and assess many disparate sources of information in and outside of the school. Thus, the teachers are faced with the challenge of creating an educational environment that nourishes innovation and constructivism, and treats children in a more individualised way, for example through differentiated teaching. To support these issues, we see a general movement within the educational practice of the elementary schools towards interdisciplinary project work where the students collaborate in semi-autonomous groups, not unlike the structure of *loosely coupled workgroups*, as described in Pinelle & Gutwin (2005). The project work aims at creating involvement and relevance in relation to the surrounding environment, drawing on resources from society as well as school facilities. Moreover, the project work form is characterised by reaching beyond the traditional boundaries of the classroom, calling for a more flexible use of the school’s physical space and resources. The students move between different locations, for example the classroom, library, hallway etc., utilising available resources and transporting materials across locations, as well as moving beyond the school borders to get hands-on experience with the topics in question. An added educational as well as technical challenge thus lies in enabling teachers and students to carry their information with them in a way that allows easy access to whatever technology they have available during the project work, that is, supporting collaboration in mixed environments. Our locus of design in this context in many senses resembles the discussion dealing with the support of mobile work presented by Bellotti & Bly (1996), and Luff & Heath (1998), in that, rather than focusing on providing increasingly complex PC-based support for distributed activities, we should consider it in terms of mobility, and the understanding that support for mobile work must be realised through a combination of different technologies that supports "…an individual's ability to reconfigure him or herself with regard to ongoing demands of the activity in which he or she is engaged." (Luff & Heath, 1998, p. 306)

Looking specifically at project work, we move beyond the work of the individual, and look at how collaboration may be supported as the students move between different locations and assignments during the group work sessions, and which challenges this poses to the design of new technology for this field. Project work in elementary schools carries aspects of both local and remote mobility (Bellotti & Bly, 1996, Luff & Heath, 1998), in that the work requires them to move around locations outside of the school area to find project information in the 'real world', while maintaining contact with teachers and other students, or being able to save and access information gathered in and outside of the physical school environment. The importance of mobility for children's group work is well documented by, for example, Cole and Stanton (2003), Danesh et al. (2001) and Inkpen (1999), and we take these aspects of mobility seriously when designing IT support for group work in elementary schools.

With this paper we present four prototypes based on heterogeneous technology that, in combination with one another and the already available technology in the schools, meet the educational challenges and provide teachers and students with a very strong technological toolbox that lets them experiment, learn and explore to achieve their educational goals: the HyConExplorer, the eBag, the iGameFloor and the eCell. However, before presenting the prototypes in detail, we will present the setting and our research method.

## The iSchool project

The iSchool project was a 5-year research project with the vision of creating learning spaces wherein everyday cultural competences, the curiosity, and the narrative skills and desires of children and adolescents meet the outside world that surrounds them, the teacher and the school. The project aimed to develop an open and 'fluid' information technology with sufficient accessibility and robustness to support learning in and outside the physical limits of the school, based on the development of software infrastructure, GUI's and spatial concepts for new interactive school environments. Teachers and students were provided with the means of experiencing coherence between the use of digital and physical materials across school libraries, classrooms and on fieldtrips.

We believe that good design cannot be achieved without the committed involvement of the teachers and students, who are the usage experts when we deal with teaching and learning in the schools. In the following, we briefly present the schools with which we have worked and the research methods we have applied in this setting.

## Research method

We belong to the action-oriented research tradition that has grown out of the Scandinavian cooperative design tradition (e.g. Bødker, 1991, Bødker et al., 2000, Greenbaum & Kyng, 1991 and Schuler & Namioka, 1993) and consequently, we understand design as a cooperative, iterative process which crosses boundaries between work practices, and which must involve active participation from a wide range of contributors. Consequently, the techniques for supporting design in interdisciplinary groups must support this ’multi-voicedness’ (Engeström, 1987) by creating an open and dynamic design space for all stake holders. This is reflected in the methods we have employed to both attain a fundamental understanding of the challenges present in the school environment, and to elicit design requirements for our prototypes. Thus, we have relied on more traditional ways of getting insight into a use practice (e.g. field studies and open-ended interviews) as well as devised new methods to understand the impact of the introduction of new technology, and to access areas of the children’s lives to which we had poor or no direct access (i.e. after-school and family activities) (e.g. see Dindler et al., 2005, Iversen & Nielsen, 2003, Nørregaard et al., 2003).

During the iSchool project we collaborated with four different elementary schools situated in and around Århus. In the process of designing the four prototypes, we hosted more than 30 design workshops and prototype evaluations with the active participation of teachers, students, school administrators, designers, architects, engineers, programmers and HCI researchers. Each prototype has been evaluated several times in context for periods ranging from 2 weeks to one year. In our collaborative design process with teachers and students, heterogeneity emerged as a shared objective in the design of technology for school work; the teachers, in particular, searched for tools that would allow them to cover a wider range of teaching styles. Rather than expressing a need for more complex, PC-based solutions, the teachers and students requested a more diverse palette of support for their everyday work. In the following, we present the four prototypes we designed with this request in mind: the HyConExplorer, the eCell, the eBag and the iGameFloor. For each prototype, we present a scenario that demonstrates the prototype in educational use, emphasising the relationship between the diverse prototypes. The scenarios are synthesised from our empirical material to show key aspects of the prototype and are thus all based on authentic observations but do not necessarily originate from one episode.

# Dressing up for school work with heterogeneous technologies

To meet the educational challenges described above, and address the needs for more diverse tools for school work, we experimented with many different types of technologies to test their strengths and weaknesses within the school context. While the PC offers adequate support for many individual tasks, the teachers put particular focus on acquiring tools for collaboration that also supported:

- Learning by doing and constructing new content and meaning
- Nomadic aspects of school work to support learning in context
- Differentiated education that allows each student to progress according to his or her current level and potential
- Collaboration in adhocracies
- A variety of learning types, for example, kinaesthetic learning

Each of the resulting prototypes provides strong support for one or more of these issues, but none of them cover all; their diversity encourages teachers and students to select or reject any given tool in the toolbox, depending on the task at hand.

## The HyConExplorer – supporting nomadic learning in context

As described above, it is becoming didactically desirable as well as technically possible to move school work outside of the classroom, and take advantage of the rich sources of information available beyond books and computer screens. It is, for example, possible to read a book about construction work and gain basic knowledge of what constitutes working at a construction site, but the book has no way of conveying how work is coordinated, how noisy the environment is, how safety is ensured through the action of the workers, etc. Taking a field trip to a construction site is a much richer source of information if we wish to properly grasp the working conditions (Figure 1).

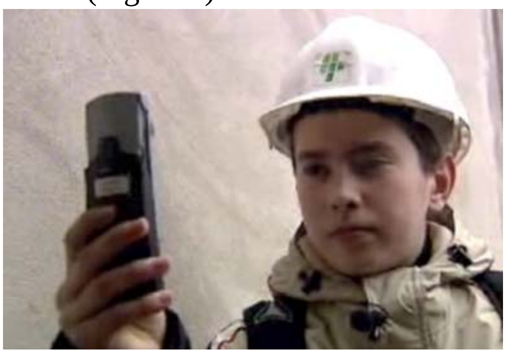

**Figure 1 - school work in the field**

We have been inspired by a number of projects that aim to move education out of the classroom. Gay et al. (2002) present some interesting pedagogically founded perspectives on how mobile technology may support the natural science subjects in the field, e.g., data gathering and cooperative learning. However, they do not consider how context specific information and services can support fieldwork. Ambient Wood (Rogers, et al. 2005) is another fine example of how we may move education out of the classroom. Their goal was to provide pupils with: *"contextually relevant digital information during their explorations of the woodland at pertinent times that would provoke them to reflect and discuss among themselves and the facilitators its significance and implications for what else was around them."* (Want, et al., 1995 p. 45) We agree with the importance of supporting reflected learning but we also see a great need and great possibilities in supporting constructive contextual feedback from the pupils, allowing them to produce material tied to the current activity and location. Providing teachers and pupils with tools of contextualization is thus essential to support the learning process in the field and project based education in general.

The HyConExplorer is a geo-spatial hypermedia system that supports project based education and learning outside of the classroom through contextualisation of information, and is in itself an example of an integrated collection of heterogeneous technologies (see Figure 2). The basic concept of the HyConExplorer is to augment physical space with digital information structures. The HyConExplorer *tablet* edition is designed to run on tablet PC's equipped with a mounted camera for capturing low resolution images, video, and audio, and a Bluetooth enabled GPS unit for recording the user's physical location. HyConExplorer/J2ME is the second generation of mobile hypermedia systems developed on the HyCon framework. The system is designed to run on a much simpler hardware setup than the tablet PC version, namely directly on *Java enabled SmartPhones* with built-in cameras and microphones, which communicate with sensor equipment using Bluetooth. For more information about the technical aspects and the use of the HyConExplorer, see Bouvin et al. (2005), Bouvin et al. (2003) and Hansen et al. (2004).


**Figure 2 - The HyConExplorer prototype pack and the HyConExplorer in the field**

An example of usage: part of the curriculum for 8th graders is the study of consumerism, particularly how products are marketed towards teens and tweens. In addition to traditional textbook material about the subject, a group of 8th graders were equipped with the HyConExplorer prototype during a one-day workshop session. To bring the classroom closer to the real world, the session was conducted in the shopping district of central Aarhus where teachers presented the purpose of the day after which the students were split up in smaller groups and went to explore retail consumerism at first hand (Figure 2). They visited different shops in the vicinity where they interviewed shop keepers and customers, took pictures of store fronts and merchandise to identify and discuss the different strategies used for marketing products for teenagers. The HyConExplorer kept track of where and when the different types of material had been collected, and gave the students an overview of the entire set of collected material with geographical markers on a map. After returning to base, the students could look through, discuss and rearrange the collected material into a presentation for the rest of the class, and for publication on a project website[1].

Thus, the HyConExplorer supports both access to existing digital information, and the production and collection of information in context. Furthermore, as the students leave traces of their project activities behind, by tying picture, text or video annotations to a physical location, it becomes possible for them to revisit the information in context, or let other students with a similar project 'bump into' this, and use it to enhance their own work. In this way, the layers of annotations will eventually form a rich, constantly expanding tapestry of information, in situ.

The use of a mobile phone, particularly in combination with the HyConExplorer software, is an example of a dedicated technology directed towards school work beyond school premises. The HyConExplorer provides support for nomadic learning, learning by doing and the construction of new content and meaning.

## The eCell – supporting collaborative work in adhocracies

Remote learning has been the focus of many research efforts within the CSCL research community as networked computers provided learners with the possibility to contribute to a common learning environment without being physically present together. E.g. web support for learning has been on the agenda in the computer supported learning communities for many years, introducing a

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[1] See http://www.daimi.au.dk/~fah/hycon/konsumus/konsumus-avis.html

number of primarily administrative systems for sharing documents and awareness about classes and group work (Clulow & Brace-Govan, (2003), Hampel & Keil-Slawik (2001), Heo (2003) and Neville et al. (2003)) and examples of how collaborative technologies can create virtual classrooms (Neal, 1997) or 'Resource Rooms' (Lau et al., 2003). Other systems for remote collaborative learning environments use a strong didactic focus as the point of departure. Abowd (1999) focus on promoting social awareness in learning communities like the Viras system (Prasolova-Førland & Divitini, 2003). eLearning has thus been primarily concerned with developing advanced technology for supporting distributed, remote learning because the gain and flexibility of this area is so obvious.
However, more efforts are being put into investigating how in-formation technology may also improve collocated, collaborative learning because there is equally much to be gained from enhancing the current learning practices through mindful development of technology to support collaboration in the primary schools. Ulicsak et al. (2001) propose tools for supporting young children (9 – 10 years old) in cooperating with each other as well as reflecting on what they're doing. Scott et al. (2003) provides an excellent study of how technologies such as large screen displays and handheld devices impact children's face-to-face collaboration and stress the importance of designing flexible hardware and software.

The eCell is a temporary collaborative niche for group/project activities in school environments, consisting of a private, inner display and a public, outer display (Figure 3). The eCell was envisioned as a flexible IT-supported installation to be placed in the unused public spaces of the school. Our intention was to include the entire school premises in the learning environment, including the corridors. The intention was to create a dynamic school environment in which the students' could claim unused space as the need occurred, and thereby work with their private materials *in* the public space. In return, the group of students would be able to give something back to the public school environment by sharing parts of their current work with people passing by the eCell.

The inner display of the eCell consisted of a 42"plasma screen with a SMARTboard™ overlay. This setup was powered by a Dell Dimension XPS PC, and provided access to the students' digital portfolios through a BlipNet access point network and a BlueTooth dongle. Peripheral devices included a LogiTech wireless keyboard and mouse. The outer display consisted of 60" diffusion screen for back projection, combined with a 1700 lumen InFocus™ projector. The outer display was powered by another Dell Dimension XPS PC. For more information about the eCell, see Brodersen & Iversen (2005).

An example of usage: a group of students have just attended a briefing session with their teacher to start on their new, interdisciplinary project about moving away from home. The group has to investigate the numerous practicalities related to getting a place of one's own for the very first time, including making a budget, looking at insurance options, and opening a new bank account. Trying to determine how to approach the task, they go to the nearest eCell and access their project folder on the inner display. They brainstorm about all the things they need to cover, and take turns using the SMARTboard™ pens to write down their agreed-upon plan for proceeding with the project over the next few days (Figure 3). The teacher drops in to hear how the group is doing, and suggests that they plan a meeting with a financial advisor at the local bank to help them get an overview of the many expenses connected to moving away from home. They save the plan and the brainstorming notes in their project folder, and the group leaves the eCell. During their work with the project, the group use the eCell on several occasions, and they start posting some of their project material on the outer screen to inform the rest of the school of what they have been up to. The publication of the project material provides the group with new input about the project theme from other students and teachers who have been watching their progress on the public screen of the eCell.

**Figure 3 – the eCell from without and within**

Whereas the HyConExplorer technology provided IT support for project work in the field, the eCell provides a flexible space for ad-hoc collaboration 'at home', where small groups can work in private on the inner screen, while engaging the rest of the school through what is made public on the outer screen.

## The iGameFloor

IT support for public schools has primarily been designed to support traditional class-room teaching placing the students in front of a PC monitor using mouse and keyboard as input technologies. However, current literature (e.g. Carbo et al., 1991) points to the fact that children have different learning styles (kinesthetic, visual, and auditory) and thus technologies for educational purposes must reflect the same range of learning styles. IT support for kinesthetic learning has, so far, not been fully covered in CSCW literature. In the iSchool project, we wanted to experiment with the use of an IT supported kinesthetic learning environment that used an interactive floor technology.

Interactive floors have emerged in recent years, and can be divided into two main categories: sensor-based and vision based interactive floors. Sensor-based interactive floors are typically utilized in dance and performance set-ups e.g. the prototype Magic Carpet (Paradiso et al., 1997) and Litefoot (Fernström et al 1998). The prototypes are sensor intensive environments for tracking the movement of feet and in the case of the Magic Carpet the sensor floor has been supplemented with sensor technologies for tracking the movements of the upper body and arms. The Z-tiles concept (Leikas et al. 2001, Richardson et al., 2004), and the LightSpace™ technology are existing interactive floors based on tiles and sensors to provide entertainment environments. In contrast to the sensor-based floors, the vision based floors support a more fluid and natural interaction on a floor surface. iFloor (Krogh et al 2004) introduces an interactive floor facilitating debate based on SMS and email contributions. A projector mounted on the ceiling is connected to a local computer to provide a display on the floor. The floor interaction works on the basis of a vision-based tracking package (Nielsen & Grønbæk, 2006) analyzing the rim of the interface based on a video feed from a web-cam also mounted on the ceiling. We wanted to combine the best features from existing sensor based and vision-based interactive floors in a novel interactive floor setup with vision tracking limb contact points from below the floor surface.

The iGameFloor is built into the physical floor of the assembly hall (Figure 4). The iGameFloor is a 3 m deep well, covered with a projection surface. The projection surface is a 3x4 m glass sheet, approximately 9 cm thick, divided into four tiles. The glass surface consists of 8 cm of load-bearing glass, a 3 mm Fresnell diffusion layer, and a 6 mm thickness of hard protective surface glass. The four tiles are supported at the outer edges, and have an internal conical frame resting on a central supporting pillar. The four Web cams associated with the projectors are managed by a tracking client running on a Dell 9150 that runs the vision software, supporting fine-grained tracking of limb positions. The limb positions are communicated to the application machine feeding the four projectors. The tracking client can be switched to a mode in which it uses a ceiling mounted wide-angle Creative™ webcam for coarse-grained tracking of body contours from above. For more information on the iGameFloor, see Grønbæk et al. (2007) and Iversen et al. (2007).

**Figure 4 - the iGameFloor in use and the game construction interface on PC**

An example of usage: A group of hearing impaired students, aged 9-12, is studying the relationships of individual words to broader language concepts as part of a school project. The teacher and a group of older students have formulated a learning target aimed at understanding how words are related according to their kinship within broader concepts (e.g. banana, apple and orange belong to the broader concept fruit). Initially, they talk about different broader concepts (furniture, cutlery, flowers etc) and find examples in books and on the internet. Using the iGameFloor game construction interface, they formulate different exercises for the interactive Floor. To the question: “Which animals belong to the category of rodents?” the students choose a number of correct answers (mice, rats, etc.) and a number of incorrect answers (dogs, cows, frogs, etc.). A total of 10 questions constitute a learning game, which can be played by the students individually or with others at the interactive floor (The iGameFloor) in the assembly hall. They submit the game that they have made to a group of younger students, and they play it as a collaborative game with 4 participants (Figure 4). The questions are spoken aloud, and the participants then choose correct and incorrect answers from the visual areas. The collaborative game environment makes them negotiate the correct answers through oral communication. As the hearing impaired students use their hands and feet as cursors, they have limited access to their use of sign language. Thus, they practice their speech and hearing skills in a motivating and collaborative learning environment.

The iGameFloor concept is inspired by Gardner’s (1993) work on multiple intelligences which is based on the hypothesis that there is a connection between body movement and language development. By stimulating bodily skills (movement), as a supplement to traditional speech and listening instruction, we could enhance the linguistic capabilities of hearing impaired students in particular. Thus, the iGameFloor supports kinaesthetic interaction and collaboration.

## The eBag

Looking at how mobile technology has been introduced in education, we discover that many systems focus on introducing mobile technology to support a traditional classroom type teaching in (Abowd, 1999, Scheele et al., 2003) and outside (Chang & Sheu, 2002) the classroom. A possible explanation for this is that a considerable number of the projects are dealing with higher education (Haderrouit, 2003, Schneider & Synteta, 2002) and consequently the lecture format which is still predominant for teaching at universities. However, the introduction of the concepts of mobile learning (m-learning) (Georgiev et al, 2004) and particularly ubiquitous learning (u-learning) (Jones & Jo, 2004, Ogata & Yano, 2004, Verdejo et al., 2006) emphasises the development on technology and general learning environments to support learning through different mediums and in different places. Verdejo et al. (2006) and Weal et al. (2003) present two fine examples of how we may move education out of the classroom. Verdejo et al. (2006) describes technology for learning activities involving tasks of preparation, data gathering, data analyzing, visualization and modelling aimed at 12-year old students. The Ambient Wood project (Weal et al., 2003) presents an example of how we may provide students with contextually-relevant digital information that would support them in discussing and reflecting on what they were doing and learning. However, the use of mobile technology is, naturally, not limited to use outside. Ogata & Yano (2004) presents JAPELAS (Japanese polite expressions learning assisting system), a context-aware system to help learners choose the correct form for addressing other people in-situ based on information about the social hierarchy. Common to these examples and a parallel to our work is the understanding that ubiquitous learning requires the seamless support of learning activities across technologies, social settings and physical locations

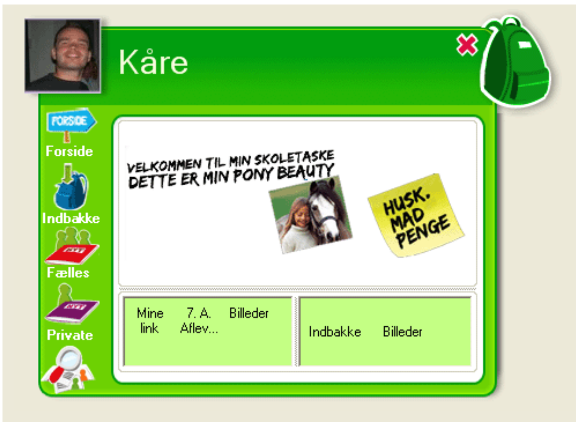


**Figure 5 - an open eBag**

The eBag is a digital counterpart to each student’s physical school bag (Figure 5). It is a web based portfolio system with seamless proximity-based login from all interactive surfaces in the physical school environment, for example in the eCell or on a traditional PC. Consequently, it serves as a link between different types of displays, through which its contents can be accessed, and it allows the students to collect, carry, access and share digital information very easily. Thus, the eBag is the student’s personal, digital repository in which they can place pictures, video, music, text documents and other digital material for use in and outside of school. With the eBag, focus is on the ubiquitous aspects of web support in learning environments that allows the digital information to travel seamlessly across technological platforms. Taking advantage of the current context when placing and retrieving information provides the teachers and students with a sense of seamless interaction with the digital material.

The eBag infrastructure is written on top of the context-aware HyCon framework and collaborative web services based on Web-DAV. The proximity-based login is based on a Bluetooth sensor network and the eBag itself is 'tied' to a mobile phone with Bluetooth capabilities or a BlueTag which the students carry with them. Thus, whenever the students are within reach of a sensor, their eBags will appear on the display connected to that sensor. For more information about the eBag system, see Bouvin et al. (2003) and Brodersen et al. (2005).

An example of usage: An 8th grade class is working with Ohm's Law, and the physics teacher presents the project to the class (Figure 6). She divides the class into groups by dragging selected eBag icons into close proximity. She distributes a new project folder about Ohm's Law to the different groups by dragging the project folder onto the group icon; for some of the weaker students, the teacher has prepared additional material, and the stronger students receive more challenging assignments, thus supporting a differentiated teaching strategy. Now, the students can access the new group folder on any PC, SMARTboard™ mobile phone, eCell, iGameFloor, etc, on which the eBag application and a Bluetooth sensor is installed. One of the groups chooses to work on laptops, and as they open the computers, their eBags immediately become available on the screen (Figure 6).

The eBag provides a flexible infrastructure for students and their teachers across different technologies, including all the other prototypes. It supports differentiated education because it is personalised, and serves as a digital portfolio as well as a communication tool between the teacher and the students.


**Figure 6 - eBags in use across technologies**

# Heterogeneous technology in and beyond school work

The four prototypes we have presented provide teachers and students with a rich collection of resources to equip themselves for doing school work, that is, we deal with a palette of technologies that have been designed with the same conceptual line of direction, but are based on, and take advantage of different technological platforms. Thus, the prototypes create a structure that allows, but which does not prescribe, differentiated teaching, which offers support for teachers and students when they work in adhocracies, lets the students seek out different places of learning in and outside of the school, and allows, for example, the use of the body in interaction with the technology. The prototypes provide a very flexible framework within which teachers and students can define the contents to suit their curriculum and style of teaching, and as such should be seen as enabling rather than dictating learning. This is not unlike the approach presented in Bentley & Dourish (1995) which calls for a new orientation in supporting flexibly organised work by providing "… a framework within which activity can take place, rather than structuring activities themselves.", that is, providing a *medium* for cooperation rather than a *mechanism*. (p. 135). Our vision for educational technology has never been to banish stationary and laptop PC's from the school setting, but to demonstrate that they can be complimented by different types of heterogeneous technologies that represent different opportunities (and limitations) in an educational setting, and which transcend the practice of sitting students in front of a traditional PC. The four prototypes presented here are our first examples of how this may be achieved, and we hope to see many more tools to enhance the educational toolbox, and that make it easier for teachers and students to 'dress up' for school work.

However, the message of this paper is not limited to academic settings, but has applicability for CSCW in general: for example, the dynamics of school work, that is the flexibility and ad-hoc nature of project work, as well as the constant focus shift as students and teachers go from one class and topic to another, is comparable to the multi-tasking within multiple collaborations observed, for example, by Gonzalez & Mark (2005), where people continually switch between different collaborative contexts throughout their day. Thus, we firmly believe that we could benefit by mindfully seeking heterogeneity, in accordance with the purposes for its implementation within any area of application. The vision of ubiquitous computing is the fluid transfer of data and services across different environments via various available resources, and the design of technology to support this, particularly with respect to supporting collaborative work in the ubiquitous computing environments, which should exploit the advantages (and keep in mind the limitations) of the many different types of heterogeneous technologies available today. Like Bellotti & Bly (1996), we are 'moving away from the desktop computer', but we have not abandoned it altogether; it may be likened to a Swiss-army knife, with an application area unparalleled in the area of information technology, if we design for its strengths rather than its weaknesses. The key in CSCW, as in the support of mobile work, is to think in terms of creating flexible toolboxes of technologies that let users select from a variety of tools, and thus embrace heterogeneity as a core constituent in the design of CSCW systems.

# Conclusion

In this paper we propose a view of heterogeneity as an asset to design, and have demonstrated how designing for heterogeneity in a school environment resulted in four very different prototypes. Each of these has its strengths and limitations, but together they represent a wide selection of diverse but interconnected tools which allow teachers and students to 'dress up' for work, depending on the task at hand. This approach has the power to inform the design of CSCW systems in general, by focusing on the advantages of the various available technologies, without sacrificing the wholeness of the context of their implementation, and thus creating a wider selection of tools, systems and applications for collaboration.

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