Snøkult: Designing a multitouch table for co-composition in an educational setting

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ABSTRACT
Multi-touch tabletops have noteworthy and promising affordances for co-composition as an activity in co-located and collaborative learning. In this paper we describe the use of co-composition as a guide in design of a multi-touch application for a museum’s touring two-day workshop on architecture.

The goal of the application is to support groups of students (12-13 year-olds) when they are creating, selecting, organizing, and presenting digital representations (co-composition) for an architectural workshop project.

The goals of the application are discussed in relation to specific features in the user interface that we designed to take advantage of a multi touch approach. We ask how these features relate to co-composition and the pedagogical aims we had for the touring workshop.

The features we envisioned would benefit from more well known standards for gestures and user interface components for multi-touch tables.

Author Keywords
ACM Classification Keywords
User interface design, Activity centered design, Collaborative content creation, Interactive learning environments, Collaborative learning

General Terms
Creativity Support Tools, Input and Interaction Technologies, Visualization, User Interface Design, E-Learning and Education, Children

INTRODUCTION
Multi-touch tabletops have gained interest among educational researchers due to their affordances for co-located and collaborative learning [1, 6, 9]. The direct manipulation of representations by fingers, and the immediacy and visibility of these movements for others, seems like a natural way of working on, sharing, and talking about the same digital material [8, 15]. However, while multi-touch applications seem to be playful and engaging for learners, it is generally acknowledged that there is huge potential for improving these digital environments in terms of designing more intuitive gesture interactions [11] and input methods that transcend traditional mouse and keyboard-based designs [19].

In this paper we have explored how tabletop interaction can be designed with features for co-composition. By co-composition we mean the act of creating, selecting, and organizing content by at least two people [23]. We view co-composition as integral to an advanced collaborative learning activity, and we describe and discuss features in the interface for multi-touch applications that aim to capture the complexity of this activity.

We address the real-world needs of the National Museum of Art, Architecture and Design in Norway and its plans for a touring workshop for middle school students (12-15 years old) on architectural design. The aim of the pedagogical and interaction design is to foster learners’ creative, collaborative, argumentative and presentation skills in architecture in a two-day workshop called Snøkult. The workshop activities move across physical sites and are modeled on the practices of the internationally renowned Norwegian architectural firm Snohetta. The students’ task is to develop and present a conceptual design for a new cultural center for their town using the multitouch table as a central compositional tool. A full-scale pilot study was conducted by the University of Oslo with a prototype of the Snøkult multitouch application, in collaboration with the museum, Snohetta, and a middle school class in Oslo [21].

The prototype for the pilot was based on a multitouch framework developed by Durham University [10]. Based on specifications developed through this prototyping and piloting, Edinburgh Napier University created the final application using the Adobe Flex/ActionScript framework. In this paper we trace the development of the final application through key design phases.

RELATED WORK
An analysis of the educational potential of tabletops points to co-location and collaboration as central areas of interest to researchers [6]. Four aspects to consider are identified: individual user – system interaction, teamwork, classroom orchestration and the socio-cultural context. We paid
attention to these general aspects in our overall application design, however we had a particular focus on support for co-composition as an integral collaborative and co-located activity. We looked at suggestions for interfaces in the literature in terms of orientation and position along the table, territoriality, and the relationship between individual and collective actions. A review of key findings is presented to situate the design approach taken in Snøkult, described in greater detail below.

Orientation and position
In a special issue of Computer Graphics and Applications, the topic of ‘interaction with digital tabletops’ is introduced and it is argued that researchers need to rethink the kinds of activities, types of social interactions, and interplay between digital and social when considering how needs can be supported using digital tabletops compared to standard desktop computers [16]. In particular, it is highlighted how the desktop metaphor is unsuitable for supporting user interaction in this digital workspace, due to interface items that can be physically difficult to reach, textual information that can be difficult to read from across the table, and the state of standard interface components that can become ambiguous when viewed from different angles. Similarly, there are orientation and control problems related to designing for more than one user, suggesting that new sources of inspiration are needed to develop metaphors for designing solutions that are compatible with user experiences [2].

Territoriality
A spatial structure of the tabletop has been explored to support players in assuming individual roles without allowing a single player to take over the game [1]. This is done by using spatially separate but sharable territories and resources to facilitate negotiation and learning from others. Collaborators use three types of tabletop territories to help coordinate their interactions within the shared tabletop workspace: personal, group, and storage territories. The design implications relate to how visibility and transparency of action is provided, the size of the table space and importantly, how functionality is provided in the appropriate locality [17, 18]. The last point is also taken up in a discussion of modal spaces, i.e., a modal region on the display that supports a particular set of input actions and a visual background that indicates the space’s use [7]. Territoriality is addressed in the application design for Snøkult through features such as drawers, a shared composition and a canvas menu.

Relationship between individual and collective activity
Control and turn taking by children is investigated by rearranging seating in a classroom using a multi-touch tabletop [15]. This experiment contrasted multi-touch and single-touch, and it is noted that children spend a significant amount of time on turn-taking dialogue in the single-touch condition. The children became physical, in the sense of moving a user’s arm out of the way if they felt that it was their turn. Further, they found that children took responsibility for the design space closer to their relative tabletop position [15]. In a different study multi-touch and multi-mice interfaces was compared showing that a main benefit of touch surfaces is not just providing a higher level of awareness, but also enabling fluidity of interaction and switching of roles between co-located users [12]. Sufficient resources and non-privileged access create a more egalitarian situation, allowing everyone to participate and have a say [13]. In Snøkult, the relationship between individual and collective activity is situated in the social organization of the activity rather than in pedagogical scaffolds in the technology, with the teacher and museum educator playing a central role.

Recurring themes in the design and analyses of co-location at multitouch tabletops, then, are relations between the embodied interaction and the spatial interaction, and meso-level interactions between individual users and the collaborative requirements of teamwork. Importantly, the significance attributed these relations is based on the premise that gesture and speech at multitouch tabletops provide unique collaborative learning opportunities. In the sociocultural perspective on learning that has informed the pedagogical design for Snøkult, gesture and speech is a premise for collaborative learning through co-composition.

Supporting multi-touch co-composition
In terms of software design, it may be argued that while computers may assist children with analytical skills such as calculation, they seldom stimulate their imagination, helping them to be creative [9]. “[M]uch instructional software functions as enhanced page-turning devices, displaying information to be learned and monitoring students’ progression. There are few opportunities for children to go beyond button-pushing and mouse-clicking in their interaction with technology” [14 p. 38]. We argue that this is also the case for multi-touch tabletops, which primarily allow the user to choose from pre-designed options, such as exploring, browsing, remixing, laying puzzles or simple problem-solving.

It seems that advancements in this field is hampered by the lack of well-known standards in multi-touch interface design and in the use of gestures, which makes the user interface difficult to use and interpret [5]. Moreover, few multi-touch tabletops currently support constructive activities or allow user-generated materials to be creatively incorporated into learning activities. Coloring applications, simple drawing programs and 3D manipulations, and visual music generators are limited in supporting collaborative co-composition involving assembling or combining elements to create new representations. This is a difficult task to support, as there are many aspects to take into consideration, e.g., issues of control, collaboration, and advanced interaction options. In this aim, we propose that Snøkult may be regarded as advancing the field.
THE CASE: THE TRAVELLING WORKSHOP ‘SNØKULT’

The pedagogical design of the Snøkult travelling workshop is based on three interrelated levels of interaction: the macro-level epistemic practices of Snøhetta; the jigsaw approach to teamwork and knowledge integration in classrooms at the meso-level; and the indexical orientation to multiple resources at the micro-level of interaction (i.e. supported by multitouch co-composition). In this section we describe the workshop activities that were designed and tested in the pilot.

Modeling practices of architects

Through extensive design activities, including partner workshops, participatory design, visits to their facilities, and usability testing with young people, Snøhetta’s design processes were translated into pedagogical tasks anchored in the curriculum, including architecture and art but also inquiry-based learning approaches that entail exploration and collecting, sharing and integrating knowledge. The development of a pedagogical design to introduce Snøhetta’s epistemic practices into a classroom setting involved the active engagement of the architects, museum educators, teachers and learning researchers, bridging the respective institutional settings of school, museum, and architectural firm.

The travelling workshop activities were modeled on Snøhetta’s design practices, which are characterized by an open and flat structure of knowledge sharing. Snøhetta strives to practice a democratic approach to the flow of information in a project, where one team member, regardless of expertise and role, has the same knowledge about the project as the next team member. This approach fosters discussion and the sharing of ideas in all phases of the architectural design process and is a cornerstone of the firm’s identity and success. Similar to Snøhetta, the curator and the teacher played their respective institutional roles in introducing and maintaining the democratic knowledge sharing ‘rules’ in the students’ interactions, which were taken up by the students to regulate their collaborative work. The Snøkult application served as a tool to collect students’ digital materials at different points in the design process, making various types of resources available as the groups collaborated on composing different presentations of their architectural designs.

Expert groups and jigsaw

In terms of teamwork and classroom organization, which we situate at the meso-level of interaction, the jigsaw strategy was employed in the pedagogical design. Jigsaw is an instructional method that encourages peer teaching by cultivating an expert role for each member a learning activity [4, 20]. Students in a class were first organized into architect teams of four to six students, with each member assigned a sub-topic to research. Individual students then broke off to work in expert groups at the site of the building, researching a part of the material being studied, taking pictures and completing tasks. They returned to their starting group in the role of expert for their subcategory to complete the overall task.

On the first day of the two-day workshop pilot, the sixteen students in the class were organized into four expert groups, with topics titled ‘Place,’ ‘Environment,’ ‘Use,’ and ‘Inspiration.’ The entire class visited the building site to carry out expert group tasks. The specialized knowledge of each expert group ‘from the field’ was documented in digital photos, which were uploaded into the multitouch table (Fig. 2) and composed into whole class presentations in school on day one, using the table as interface.

On the second day, the students formed into their architect teams to share what they learned and collaborate on a physical model using blocks and design materials. Each student was an expert in one topic, holding one-fourth of the knowledge needed for planning and modeling a new cultural center for the site. The architect team ‘jigsaw’ thus integrated four areas of specialized knowledge, through both the design work with analogue modeling materials (Fig. 1), and the co-composition work with digital materials at the multitouch table. The sequence of the modeling and composition work, allowing for back and forth movement...
between analogue and digital materials, was modeled on Snøhetta’s architectural design processes. These aspects of classroom orchestration are relevant to the multi-touch tabletop in terms of its place in a larger ecology of resources and devices.

The pedagogical design accommodated the use of the multitouch table by the full class, which is the normal arrangement for touring workshops, allowing staged activities for groups of 4-5 students at a time. Pictures of the site and the models bridged the analogue and digital tabletop activities.

**DESIGN OF APPLICATION**
To design the general interface, a wooden table (Fig. 3) was employed of almost equal size to the cell screen already in possession by the museum, to closely simulate environmental circumstances. The virtual ‘table’ concept with its content can be mapped very effectively with object-oriented design and was utilized throughout design and development stages. Discussion centered on such issues as reachability, icon size, clutter, multi-sided operation, menu structure and simplicity of presentation to the student users.

Though the table appears large at first observation, screen pixels and touch sensitivity affect how objects should be sized to appear. This is considered in combination with student’s smaller fingers and arms having lesser reach. The 46” Cell screen resolution of 1920x1080 when viewed at a short distance does not give the same level of detail as an equivalent desktop PC screen.

The number of students operating the system at once was also a concern. Though the users are obviously smaller than adults in stature, limitations on the number of concurrent operations are most significantly affected by screen real estate. Toolbars associated with each object take a specific amount of area, leading to potential overlap of controls when many sets are activated at once. From experiments on the physical table, we estimated six people would be the ideal number of operators at any moment. The general interface was designed to optimize the available space.

The pedagogical design served as a basis for generating ideas of how the multi-touch interface elements and gestures could support different activities of co-composition. We present interface features that we arrived at in the final design of the application and we present these in relation to three aspects of the pedagogical design: Knowledge sharing, planning and modeling, and communicating the concepts related to their model.

**INTERFACE FEATURES FOR KNOWLEDGE SHARING**
As we have outlined, the pedagogical approach allows students to model architectural practice; first in an expert group, then re-grouped in an architect team to create a concept and vision for the new cultural center. In an architectural design process, the first phase involves developing the main idea based on inspiration from the environment, the aims and needs of the client, the general use requirements, and some simple calculations and projections regarding the orientation, functions, and scale of the building in relation to the site. The students worked on these tasks using digital cameras and taking notes while visiting the building site. Back in the classroom, they browsed and selected images on the camera and uploaded them to the multi-touch tabletop.

**Group and task management**
The multitouch application has a global menu that gives access to management features, such as snapshot saving, printing, presenting, screen saver and group/canvas changes. It was created to separate general tasks from user-specific ones. Other intentions with the target audience in mind was to minimize steps required to perform tasks and remove all reliance on underlying operating system interaction. When called the menu appear as a modal layer atop the main Canvas and the current state saved automatically to the student group’s folder. Management of students’ material for each school visit is automatically performed, and stored using DropBox in a well-organized history of work. When a camera is connected to the multi-touch table, images are displayed upon connection and imported into correct folder.

**Drawer**
The concept of drawers was identified as an interface component that could display resources when needed, but otherwise be hidden. This saved space and supported territorial control. The images in the drawers had several roles in the co-composition activity, and we designed the application to allow an indexical orientation to multiple resources and support their use as resources in the team’s negotiation and interpretation. This means that the images could be freely browsed, positioned, scaled and rotated within the drawer, allowing the students to categorize compositional resources, to be reminded about their work in the field, or to support an argument about the building design they would present. The drawers provided a modally dynamic spatial structure to the tabletop interface, in that three separate drawers contained content that served different purposes in the co-composition activity, i.e., backgrounds, building models, and an architectural entourage of figures, materials, and illustrations (Fig. 4).
As students were able to interact with drawer materials simultaneously, the teacher and curator intervened as needed to maintain productive social dynamics and interactions. The aim was for each co-located ‘expert’ to have a degree of control at different phases of the co-composition process, in terms of which images to include, in what order, and how the images were presented. Issues of territoriality were taken into consideration [17], as physical reach and embodied action give different users control over the drawers. Productive social interactions and conversational rules, scaffolded by curator and teacher, were central in mediating control of drawer content, insuring that each ‘expert’ had time to present his or her views and selections to others in the group, as they negotiated how to present their design.

The drawer is situated at either of two screen sides and pulled out containing categories of sources, including camera imports, each item manipulatable within. This allows new items to be easily brought onto screen (Canvas), but also restrains clutter. Drawers extend to about 1/3 of table width, have dual-sided controls and switchable content orientation.

**INTERFACE FEATURES FOR MODELLING**

The presentation and rendering techniques used by Snøhetta architects in the conceptual design process, which involves moving between analogue and digital forms of drawing and modeling, served as the basis for designing the resources and procedures for the students’ conceptual design presentations. This phase of architectural design uses techniques that convey the main idea of the building through composites with drawings, models, and other visual and textual references. At an early design meeting, one of the architects suggested a table setup consisting of two elements; physical modeling of the new building in cardboard and a video camera that filmed this cardboard creation against a wall projected image of the building site, creating a composite image (Fig. 5). This idea shaped further development of a mixed approach for the workshop that combines digital and analogue resources. Based on both pedagogical and technical considerations, and tested with a group of teen users, we designed the students’ activities to involve the production of two composites, which we refer to using the concept *collage*.

In the pilot study, the first collage that the student ‘architect team’ produced at the multi-touch table was based on a two-dimensional top view photograph of a model made of blocks (Fig. 1). The blocks are scaled (1:200) to correspond to a topographic map of the site and are color-keyed according to different use functions typically found in a cultural center, e.g., vestibule, stage, and café. The aim of this activity is to develop an understanding of scale and proportion, and more specifically, based on knowledge and perspectives represented by the different experts in the group, to determine the concept for the building (inspiration expert); discuss and agree upon the entrance and orientation of the building in relation to the site (environment and place experts); and decide on the types and locations of the main facilities (use expert). The curator and teacher visit and talk with the teams as they work on their models and when they presented these as collages composed on the multitouch table.

The second collage the architect team produced at the multi-touch table was based on a three-dimensional view of a model of their building. The model was made at the analogue table using materials selected from an inventory provided by the curator and Snøhetta specifically for the touring workshop. It is through this work that students gave form to their building, reflecting on use of materials and forms in relation to the concept, environment and use. The students take a front view picture of the finished model against a ‘green wall’ to create a 3D image, which is then uploaded to the multi-touch table. In architectural presentations and renderings involving 3D views of models, composites often involve the superimposition of a model onto photographs of the actual site, illustrating the material finishes and how the proposed building is sited and relates to the surrounding environment.
Sometimes there is a need to position and scale elements within a collage, and sometimes it is desirable to position and scale the collage as a whole (i.e. all the elements remain grouped, or as a fixed stack of images). In keeping with the overall design aim of ease of use, it was decided not to introduce new or unfamiliar gestures, as this would require instruction and add another level of complexity to the co-composition task. Rather, we introduced modes of working with superimposition (Fig. 7), locked and unlocked, which were triggered and indicated by a button that was either green (unlocked) or white (locked). Fixing and unfixing the collages allowed students to situate and scale individual elements and images on a selected background, and once placed, to lock and then scale the composition as a whole.

**Making and fixing collages**

General multitouch gestures are employed to enable placement of objects on the Canvas. When an image is added, transparency is activated and objects in the layers beneath are visible, allowing a collage to be composed in layers.

Toolbox items each have a specific purpose enabling students to make changes to the image. Tasks such as editing transparency, scaling, sketching, text annotations, hot spots, layering, duplication and deletion are supported. As toolbars are attached locally to each image on screen, multiple students can complete their work in parallel.

Text annotations or sketches as separate objects can be easily edited, re-located, or linked with hotspots independent of the image they may be associated with. Functions available to the user then depended on the type of object, with tool-specific functions shown in the vertical toolbar.

**INTERFACE FEATURES TO COMMUNICATE EXPERTS’ CONCEPTS**

At the multi-touch table, the students used four different kinds of images as background canvases for their collage activities depending on the task, i.e., their own eye-level pictures from the site, scaled maps, or aerial views. Once the models and other compositional elements were selected, scaled, edited and in place, students added the final multimodal textual layer: visual and textual representations that explained and communicated their ideas for the group’s design.

The interface feature addressing this activity was designed using the metaphor of **hotspots**, which are added by selecting either a hotspot ‘image’ or a hotspot ‘text’ icon (Fig. 7). Schematic and conceptual presentations to clients are an established part of architects’ practice, which inspired the use of the hotspots in the context of the collage. The hotspots add a descriptive layer, e.g., highlighting the functions of different building parts, the choice of materials, and inspiration from the building site or other sources that are important to the design concept. A touch keyboard appears when selecting the hotspot ‘text’ icon for adding labels.

![Figure 7: Composition and adding hot spots](image-url)
EVALUATION AND DISCUSSION

Young people’s physical experiences, in particular during the visit at the building site and during physical modeling, were central drivers for appropriation and meaning making on multiple levels [21]. The design of the Snøkult application aimed for a similar level of engagement and meaning making during the activities at the multitouch table, supporting learning activities and co-composition as the groups moved from physical table and modeling materials to composing with digital representations.

Our findings may be linked to two on-going discussions in the multitouch design research. First, the Snøkult designers shared an interest in the aims of multitouch metaphors of ‘natural’ interaction, or the ‘disappearing metaphor’ [24]. However, we experienced that a ‘natural’ interface was difficult to accomplish in the design as the complexity and creative aspects of the learning activity became increasingly apparent. This was particularly evident when accommodating ‘mixed’ setups, where students integrated physical modeling and digital images in their composition work. The flow of materials and activities required small groups of students to select and combine images while negotiating and integrating their expert knowledge and vision for the new building. In other words, the natural interface metaphor is insufficient in a prescriptive sense other than when designing for micro-level interactions, and is unable to account for the interrelated meso-level and macro-level aspects of the sociocultural context that are relevant as design considerations.

There is an elusive balance between letting users explore multi-touch systems on their own on one hand, and guiding users, explaining how to use and interpret the user interface, on the other [5]. This gap was made apparent when the technological designs were tested in our lab with youths the same age as the students. The tests had a usability focus, and revealed that the young people needed to have the idea of co-composing a collage explained, and needed some experimentation to accomplish the task. The metaphoric idea of collage was grasped easily, but the interaction related to stacking and fixing required explanations and experimentation. We propose that a broader range of resources and digital practices be included in the concept of natural interaction with multitouch tabletops, and that this may be accomplished by greater user involvement in the development of metaphors in design, e.g., the source of metaphors, the translation to the interface, and how the interface representations – along with other, multiple resources – mediate learning activities.

Second, we have utilized a multi-touch table as one element in a multi device setup with activities spanning both analogue and digital content creation and negotiation. We used digital photography as a bridging activity between the site visit, the physical modeling and the activity at the table. The digital media from the cameras were uploaded to the multi-touch table and retrieved in the drawers, but not without help from the curator. There is still a way to go for multi-touch tables to be integrated and to be understandable in such digital ecologies. Our future work will include mobile devices, and we will explore how activities can be more integrated. As an example gestures for ‘swiping’ material between devices are explored [10].

On a more general note this case also shows the potential of a material perspective on learning in doing [22], as the type of hybrid ecologies reported here allows children to engage in practices of design and engineering (although simplified ones and as newcomers). This perspective highlights the closely-knit assembly of collaborative problem solving, material and embodied enactments, multi modal co-composition related to design and argumentation, and the appropriation of curricular defined conceptual knowledge. An important aspect of such learning environments is the opportunity to embrace children’s own practices, and augment them in ways that values multiple ways of working [3].

CONCLUSION

Through extensive design activities, including partner workshops, participatory design, visits to their facilities, and usability testing with children, we have translated the Snøhetta development processes into relevant pedagogical tasks that are anchored in the curricular aims, such as exploring, collecting, sharing and integration of knowledge. These activities were the basis for design and development of a pedagogical plan and a corresponding multi-touch application. We identified a set of interface features that we imagined could support the pedagogical tasks, and composition in particular: Drawers for sharing and negotiating resources, collages to integrate and visualize knowledge, and hotspots for communicating concepts.

This comprehensive design has been implemented both as a research pilot and as finished software. Evaluation and experiences so far suggest that the interface elements of the multi-touch application was a challenge for the generation of multi-touch tables we used, in terms of resolution and accuracy of the touch recognition. Irrespective of such technical limitations the interface level posed challenges in terms of how gestures and common interface elements in this genre are understood and ways to support more advanced interaction designs.

We are currently exploring a new generation capacitive multitouch tables, identifying affordances for co-composition and possibilities for designing new interface metaphors.

Further work will explore how to apply the findings and principles from Snøkult more generally to a range of subjects, particularly those that combine aspects of design, creativity, engineering, collaboration and argumentation.
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