Learning with Interactive Tabletop Displays

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***Abstract*—Groupwork is core to the educational process at all levels, with peer learning activities demonstrated to be an important component in exploring new idea spaces. Recent advances in technology encourage a re-examination of ways that technology can support and expand groupwork. This paper examines how large multi-touch tabletop displays can be used by students in group information exploration, creation, and sharing situations. The multi-user, multi-touch features enable multiple people to transition between individual and group interactions with the display, rather than the turn-taking interactions common in older technologies. While this provides opportunities, it also presents challenges in the ways that activities for the shared space are crafted, executed, and evaluated. This paper describes how our software solutions encourage idea exchange, sharing, and awareness of the activities of others, toward crafting better artifact-centered educational experiences. Specifically, the paper describes three techniques for card-based explorations that help enable groupwork: semantic zoom, dynamic grouping and info glow. Semantic zoom considers how pinch zooming can vary not only artifact size but also artifact content, showing more information at larger sizes. Dynamic grouping features the card combination which facilitates idea generation and synthesization. Info glow highlights artifacts that have been recently accessed or changed, providing an enduring way to see modifications made by others. This paper explores usage of this environment and these techniques, focusing on their impacts on educational goals and objectives for K-8 and for undergraduates, to understand how students in pairs or triads work independently and together as they explore and create within information spaces. Results suggest that older students tend to engage more with each other, though students of all ages transition between quiet individual work and communicative group work. The techniques described in this paper inform ways that they can be configured to optimize idea exchange, sharing, and awareness, and ways that tools and classroom techniques can encourage a more dynamic and engaged learning environment.**

Keywords—MUMT, multi-touch, education, creativity, collaboration, semantic zoom, dynamic grouping, info glow

I. INTRODUCTION

Collaborative learning is a widely accepted teaching approach, with potential benefits that include improving learning outcomes, supporting the development of thinking skills, increasing engagement in learning, and having a number of social benefits such as promoting prosocial behavior and acceptance [1]. Technology can be part of collaborative learning, but it is important to explore its use in a measured way toward understanding how it can best fit in the learning process.

To better understand the collaborative and engaged learning process, multi-user multi-touch (MUMT) technologies, we created and studied tools based on tabletop computers featuring the simultaneous touching to the digital materials. The MUMT technologies have several advantages over traditional tabletop displays, which may improve learning for different age levels. The high-resolution large interaction space on the tabletop not only facilitates presenting a large number of materials, but also provides room for individual student to organize ideas and for the team to integrate insights and findings. The direct touch interaction is an intuitive and attractive way to explore the digital content. The flexible and simultaneous access to the digital learning materials offers new ways for students to understand and reflect on the knowledge. The flexibility of manipulation and the easiness of sharing support the co-located students to either work individually on different problems or collaboratively on a common point of interest.

This paper examines the impacts of the MUMT tabletops on two educational goals: creativity and collaboration. The two goals are touted as benefits of the technology by the manufacturers and have been recognized as key elements in many pedagogical approaches. MUMT displays serve as a platform for students to practice generating new ideas in a collaborative manner. The digital and manipulable artifacts on the MUMT tabletop provide many ways to understand and associate the learning materials, therefore the flexibility of the interaction may help student to find inspiration. The shared space helps each collaborator to be able to see each other's activities, and it is good for building social skills and coordination skills in teamwork.

To expand the understanding of how the large interactive tabletop computers might be used to assist students in building creative thinking and practicing collaborative work, we identify 3 interaction techniques enabled by the new MUMT displays and observed them in two studies: semantic zoom, dynamic grouping and info glow. We observed the usage of the three techniques with two student groups: K-8 (kindergarten through 8^{th} grade in US schools) and college students. The findings from the two investigations are presented and discussed to foster new design for the MUMT-based learning tools.

II. Related Work

A considerable amount of work explored and designed interactions on MUMT displays. Early studies on the co-located collaboration with digital displays were technologically limited by the number of detected touch points. Single-touch devices based on fingertip or stylus input only supported collaborators in turn taking [2-4]. This turn-taking model closely resembles turn taking in traditional paper-based collaborative activities like affinity diagramming and mind mapping [5-7]. Research on collaboration with these devices focused on understanding social protocols which coordinates the turn-taking [8]. Advances in the touch technology and gesture recognition bring more affordances to the touch-sensitive displays to support simultaneous interaction. Projector-based [9] and multi-touch screen [10] devices have been developed which encourage collaborators to manipulate digital objects at the same time [11]. Applications of these devices can been seen in many area-specified scenarios such as museums [12-14], games [15, 16], data analysis [17, 18], and assistive technologies [19].

MUMT technologies have also been studied in education. Kharrufa et al. deployed multiple digital tabletops in classroom for six weeks and identified themes and factors that improve teacher-student coordination [20]. Piper et al. presented a social-skill building tool, SIDES, to help students with Asperger's Syndrome to practice working together [21]. Evans and Wobbrock conducted a study to explore the social regulation on the interactive tabletops [22]. A following up study looked into how to detect the collaborative learning process from the touch data [23]. Maldonado presented several works on collaborative learning with a MUMT tabletop, focusing on understanding the collaboration process [24], teacher intervention [25] and teacher attention [26]. Built on the previous research on the MUMT displays in education, this study further explores how creativity and collaboration are supported by different interaction techniques.

III. Engaged Learning with MUMT Displays

MUMTs afford collaborative learning and engaged learning, because the large, shared space enables multiple students to see and interact at the same time. Understanding the process of collaborative learning is subject to a variety of factors external to the technology, such as students' creative thinking and the willingness to collaborate with peers. In this study, we consider creativity and collaboration as two important factors to evaluate the usage of the MUMT display in educational settings. This section introduces three interaction techniques that we specifically explored in supporting creative and collaborative learning.

A. *Creativity*

Fostering creativity has long been recognized as one of the important goals of education. There is a growing interest in designing and developing learning tools which encourage curiosity and self-motivation in the development of personal characteristics. The affordances of MUMTs provide unique opportunities to build educational tools that help students learn to be creative: the intuitive interaction techniques free the student from learning a complex interface and therefore increase the interest and engagement with the learning materials. Furthermore, the learning materials on the multi-touch display can be augmented with animation and visual effects – the free and diverse interactions with the attractive contents may inspire more exploratory and discovery activities. In the design of the interaction techniques with the multi-user multi-touch displays, embedding rich interaction techniques to encourage creative exploration is important for an effective learning process. Educational software designers must consider how to present information on the tools in ways that not only brings up more knowledge exploration, but also better reflection on the learning material.

Touchscreen technologies bring novel and natural interaction techniques after the WIMP (window, icon, menu and pointer) era. To create a creative to collaborative learning environment, one of the first challenges is in forming a basis for the design of the tabletop environment and its associated collaborative interfaces, so that students can learn through the interaction with the interface and the communication with others. Two widely adopted interaction techniques on the touchscreen are the zooming by pinching and moving by dragging. These two touch gestures are not only widely supported by many touch devices such as phones, tablets and surfaces, but also became such embodied interaction metaphors that people make without regard for recognition or technical concerns. In a collaborative learning scenario with a MUMT display, these gestures could be used for knowledge discovery and idea inspiration.

In this exploration, we look into two interaction techniques that foster creativity in learning process: semantic zoom and dynamic grouping. Zooming in on an object suggests that the user is trying to see more details about the content. Semantic zoom means the interactive objects show high-level information at the beginning, and when the user zooms in on the digital objects with the pinching gesture, more details gradually come to the object and inform the students (see Figure 2). The dynamic grouping is an interaction technique that emphasizes free movement and flexible combination of the digital objects. By trying to combine different pairs or groups of virtual elements, the students may discover meaningful and interesting findings from different combinations, and therefore learns ways to think differently and creatively.

B. *Collaboration*

Learning to collaborate is another important goal in education. In collaborative learning, students work together in small groups and over the common goal. They might be individually accountable for their work, and assess the work of the group as a whole. Cooperative groups work face-to-face and learn to share the material and discuss with other students. A good collaborative learning process asks students to learn to work with peers, share with and listen to the collaborators, and avoid potential conflicts. Computer-supported collaborative learning is characterized by the sharing and construction of knowledge among students using technologies, in which knowledge is developed by one's interaction with others and solving the problems by the effort of a group.

The MUMT displays can benefit the collaborative learning in three ways. First, the affordance of multi-finger touching supports a pair or triad of students to use the system simultaneously, which resolves the access conflicts. This is an obvious problem when students learn with a shared desktop computer. Since traditional keyboard- and mouse-based learning tools only let students to take turns to use. Second, the shared display supports flexible and dynamic ways of collaboration: students can either work separated at different places of the display, or have a discussion over one shared material. With the capability of rich visualization, MUMT interface can also be designed to provide notifications that promote collaboration. Adding visual effects that arouse students' attention to each other's activity will potentially encourage collaborative behavior and increase mutual understanding.

To understand the collaboration with MUMT displays, we explore info glow: showing a visual effect (a glow) around recently changed objects, which notifies a person the changes made by co-located collaborators. This notification technique suggests potential benefits in enhancing collaboration, since seeing and understanding what others are doing might help students find common interests. It also probes students to keep aware of each other's activities during a collaborative learning. Even though MUMT displays support multi-person usage, changing the object occupied by others without permission might be considered bad behavior. Exploring how students recognize and react to the notification about others' activity will promote the understanding on the collaborative use of MUMT technology.

IV. EMPIRICAL STUDIES ON THE MUMT DISPLAY IN EDUCATION

To understand the use of MUMT display in educational settings and to explore how MUMT-enabled techniques of semantic zoom, dynamic grouping and info glow help groups, we conducted two exploratory studies: one with K-8 students and one with college-level undergraduates. The first was during the Tech-or-Treat event, a technology exhibition staffed by graduate students at our institute. The second one was with 10 groups of pairs or triads from a human-computer interaction (HCI) class doing a design task with a MUMT display. We explore usage in this environment, focusing on their impacts on educational goals and objectives.

We use the Microsoft Perceptive Pixel as a MUMT platform. Microsoft Perceptive Pixel is a 55-inch multi-touch display enabling simultaneous finger operations of different users like touching, pinching and dragging. We designed and implemented a card-based system on the MUMT device to implement the three interaction techniques. Cards are a common and practical media to represent ideas that support creative idea exploration. Digital cards support simultaneous moving, rotating and zooming by multiple users that provides diverse ways of information exploration. Cards are also flexible in presenting information. They can combine pictures to provide visually appealing items with textual information to support descriptive materials.

In a MUMT-supported learning environment, digital cards consist attractive materials can encourage students to explore the content, meanwhile enables simultaneous use of the display which help building a space for collaboration. For college students, cards can be observed and discussed to brainstorm novel ideas, then manipulated, organized and connected to eventually present the concept by an organization of cards. We focus on information exploration and ideation with the digital cards, where the card plays a role in scaffolding the creativity generation and collaborative behaviors.

V. EXPLORATION WITH K-8 STUDENTS

A. Card Game

Figure 1. Tech-or-Treat card game

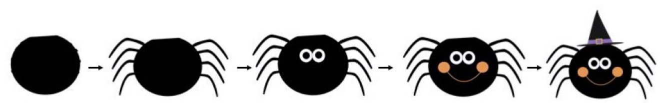

Figure 2. 5 levels of details when using the semantic zoom gesture. Note that along with increased detail, size increases as well (not shown).

As a technology demo for the Tech-or-Treat event, we implemented a Halloween Card game which has rich and interactive content (see Figure 1.). The game consists of 12 Halloween-themed cards on each side of the board. Each card has one cartoon character, such as a zombie or a baby ghost. Semantic zoom and info glow are integrated to increase the playfulness of the activity. Semantic zoom provides an easy-to-navigate, touch optimized view of the cartoon character presented to users. In the game, each character has 5 variable sizes. At size 1, the character might not be clear to the children, as only parts of it would be shown. At size 2, more of the character could be seen and this idea followed until size 5 (Figure 2). When the character is maximized, there will be a sound effect played corresponding to the role of the character (e.g. a ghost smile sound for the baby ghost). The gradually appearing content is designed to encourage exploration and discovery. We also added an inertia effect to the card. When the user swipes the card, it will glide on the display, and gradually come to the stop. When the card reaches the edge, it bounces back. To support info glow, categories in the shape of cauldrons, centered in the middle of the screen, change the color of characters dragged onto the color; then the character on the opposite side of the screen would show the info glow around it, alerting the user that it had changed.

B. *Investigation Setup*

The card activity was evaluated during the Tech-or-Treat Event hosted by our university. It is a Halloween-themed technology exposition for young kids to experience science and technology. The purpose of the event is to inspire young children by the state-of-the-art technologies and encourage them to learn about art and science. The expositors are students and faculties, and visitors are children and their families from the local area. The event lasts for 5 hours at an art center, and no ticket required for visitors.

Our game was set up in a learning studio where the visitors to the event can come up and play (Figure 3 shows the activity setup). The studio is one of the exhibit rooms to present Halloween-themed technologies. Throughout the event, one research member stands around the table to give general instructions on how to play the game. Another two research members recorded system usage. One research member counted the number of visitors, including children and their parents. The time when they come up and leave time were noted. Another research member observed and took notes of the children's interactions with the game. The data was recorded in three parts: collaboration mode, observed behaviors and description of the activity. Collaboration modes included playing individually, playing collaboratively, and playing in conflict, thus giving an overview of how children collaborate in the shared space. The 7 behaviors included exploring, showing, creating, sharing, fighting, challenging and teaching; thus describing basic activities with the technology. The brief description gives general information about how the visitors play the game. The two research members sat close to the game display and made notes on paper.

Figure 3. Tech-or-Treat game setup

VI. TECH-OR-TREAT EVENT RESULTS

During the event, 249 visitors stopped by and played with our interactive game. Among them 178 were children and the rest were parents or caregivers. The time the children stayed and played with the game ranges from a few seconds up to 10 minutes and 44 seconds, with an average of 2 minutes 4 seconds. The 178 participants formed into 50 groups, with 2 to 5 kids at the display at the same time. Among the recorded 50 groups, 7 groups played the game collaboratively with intensive communication and collaboration. 31 groups played loosely coupled, with each child using their own digital cartoon character separately. 11 groups had conflicts during play.

The semantic zoom was seen to encourage the children to explore content. Younger children were amused by zooming in and out the cartoon character. Older children were attracted by different levels of details of the characters. Some children wanted to zoom all of the 12 characters to see what the characters are. As the research member noted: the kids were *very happy to see characters getting bigger* and *kid wanted to make everything large*. When the cards are maximized and the sound played, the kids *enjoyed hearing the sounds*.

The collaborative groups discovered their ways to play together. The most common collaborative activity during the game was sharing the digital object. The semantic zoom encouraged students to play the game in a collaborative way. For example, in one group of two girls, the older girl assisted a younger one zoom the card and explained the content on the card. She also explained how to change the background color with the cauldrons. In another group of two children, they tried to zoom the cards simultaneously to make visual effects.

Though we have seen collaborative usage of the system among a few groups, 32 groups played the game in an individual way. It is especially common among children who do not know each other. Although many children were amused by changing the background color, they did not respond to the background change made by others or ask for other’s agreement before changing the color. The children swiped the cards around but did not care about whether the card gliding will intrude others’ interaction. We also observed children who have conflict during the use of the technique. For the 11 groups who have conflicts during the game, typical reasons include the conflict when trying to play with the same card, and the interference when some children zoom the card too big or too fast that other children cannot zoom their cards. A kid said *there are too many people touching it! I cannot change the color*. Since the system slows down when too many touch points were processed at the same time, it made some children frustrated when resizing characters.

VII. STUDY WITH COLLEGE LEVEL STUDENTS

A. *Card-based Design Tool*

The study with college-level students focused on a design ideation task. The card-based design application running on it consists of a blank working area in the center and design cards alone each side of the table (Figure 4). Every digital card can be moved, rotated and resized by different designers simultaneously with finger tips. A toolbox can also be found on each side of the table. Each toolbox provides a pencil tool and a commenting tool. Using the pencil tool, a designer can draw free lines of different colors and thicknesses with the finger on the table. An eraser tool and an undo tool are also provided for correction. The commenting tool is used to create a textbox in the working area. A virtual keyboard will appear when editing the comments in the textbox. Each textbox can also be moved, rotated and resized.

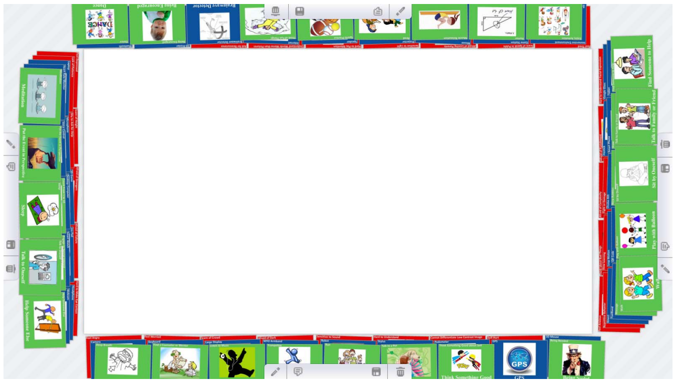

Figure 4. A screenshot of the card-based design system

The design cards used in this study are created based on three workplace factors—social context, activities and artifacts—as described in the design requirements. Accordingly we designed three types of cards corresponding to each of the dimensions: problem cards, activity cards and technology cards. Each design card has an image illustrating the content of the card, with a word or a short phrase describing the problem, activity or technology placed below the image. Different background colors differentiate design cards of different types.

The 30 problem cards include emotional problems summarized from the Preschool Anxiety Scale (PAS) [27]. The PAS is a questionnaire to diagnose emotional problems of preschool kids such as feel angry, feel anxious, afraid of dark, etc. The problem cards aim to provide hints on the context of the design and help the designers understand the emotional problems of the children. 31 activity cards show common activities like reading, walking and listening to music with which the children can alleviate negative emotions. These activities are effective therapeutic approaches carried out in an emotional issue treatment program [28], which help the kids understand and adjust the tense or extreme emotions. The activity cards shed light on possible interaction manners which the designers might associate in the design to lead the kid to achieve the emotion management goal. The technology cards have 37 popular digital devices like tablet, smartphone and Google Glass. They are provided as suggestions of technologies which the designers can take advantage of to implement the design.

In this study, we investigate how semantic zoom and the dynamic grouping help students discover and communicate design ideas. The transition between individual and collaborative work is also explored to understand how college students do creative work with MUMT display. We observed the card zooming actions and identify the collaborative meaning of the gesture. The dynamic groupings are actions that students compare and combine different cards to find new ideas. We explore how the zooming and grouping gestures are used in the design task, and expand our understanding to the impact of their usage for the educational goal.

B. Investigation Setup

The study was conducted in the Computer Science Department. Nineteen undergraduate students between 18 and 30 were recruited. As a chance to practice the design skill and learn new design methods by using the novel device, the recruitment was only open to students from two upper-level design-related classes: Human Computer Interaction (N=16) and Information Design (N=3). All participants agreed to work in a team of 2 or 3 people, and they could choose to take part in the study either once or twice.

During the recruitment, 6 students participated the study twice and the rest participated the study once. Therefore 19 participants formed 5 groups of 3 members and 5 groups of 2 members. One design group at a time used the design system to finish the design task. At the start of the investigation, the design task was described to the group. The method to manipulate the design card and draw the lines was demonstrated to the participants. Each participant then tried using the design system. After the participants became familiar with the tool, the group was informed that design outcome should be presented in a form of design poster. An example poster of a squeezing game (Figure 5) was shown and explained to the participants. After the introduction and

Remote Robot	A robot controlled by a remote tutor gives private help when a student is depressed when it is hard to catch up with the class.	Activity Advisor	A brainwave detector monitors mental distress and suggests interesting activities through a smartwatch.
Word Visualizer	A tablet application provides images to explain words in readings and the student can practice reciting hard words.	Maze Game	An immersive environment in which a child goes through a dark but safe maze to learn methods to reduce fear of the dark.
Facial Expression Helper	Google Glass captures and interprets facial expressions and a tablet replays them to help the children understand facial expressions.	Virtual Dog	The kid draws a dog with a stylus on a tablet and a virtual 3D dog appear to interact with the child using motion detection devices.
Public Speech Training	An immersive environment game helps the child reduce anxiety when talking in public.	Fear Monitor	Heart rate monitor tracks the fears of the child and Google Glass alerts caregivers about the child's circumstance.
Taking Pictures	A tablet game in which the child learns words through finishing a mission of searching and taking pictures of the listed items.	Learn to Help	A virtual environment game in which the child finishes the task of helping others to reduce the fear of communication.

Table 1. Descriptions of 10 posters created during the investigation.

training, each design team started to work on the design with the design table. Video of the entire design process was recorded by an overhead camera looking at the design table.

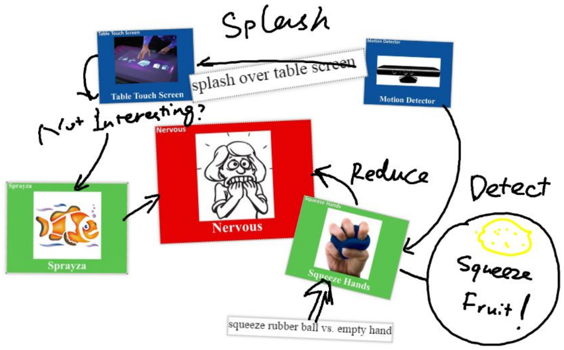

Figure 5. Example poster demoed to the students

VIII. CARD-BASED DESIGN STUDY RESULT

All design groups successfully finished the design tasks and created 10 design posters (Table 1), taking between 17 and 52 minutes. The average time taken was 31 minutes 54 seconds (SD=10 minutes 20 seconds). All groups finished the design in less than 40 minutes. Collectively, the design groups showed good understanding of the content on the design cards, with only two groups inquiring about two of the technology cards during the design period (about the MYO armband and the FuelBand).

Despite starting with the same materials and directions, the resulting designs were very different. For instance, the Fear Monitor app aims to provide in-time emotional assistance to the kids by using technologies including Google Glass and heartrate monitor. The design poster created by this team is illustrated in Figure 6. When a child feels anxious in an environment like a crowd of people, a dark place, or with strangers, the heartrate monitor detects a fast heartrate and the Google Glass plays a short video of his friend or family to give encouragement to the child. If the problem is severe, the GPS location and a picture of the child's surroundings will be sent to the parents or relatives. The caregivers can quickly seek to understand the situation of the anxious child and provide immediate help.

Participant feedback reflected that the card-based design tool promotes understanding of the design task. As one participant noted in the questionnaire about the design experience:

"*The design tool was easy to use and very effective for what we were asked to do. It provided enough cards to generate ideas*."

Inspiring creativity also seems to be supported for our participants when using the design tool. The following quotes exemplify participants' opinions about generating new ideas:

"*I think the design tool was good in giving a lot of possibilities with what I could make*."

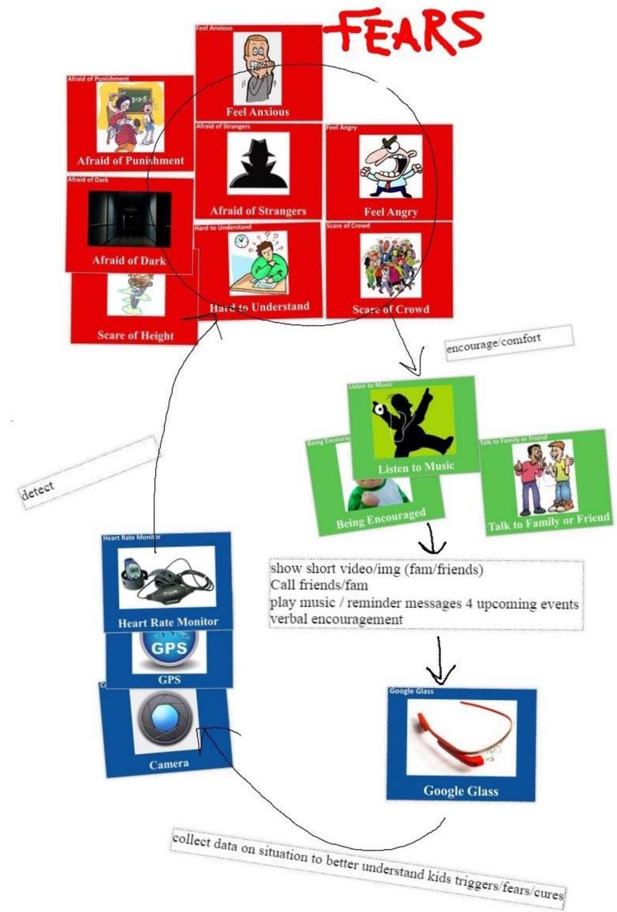

Figure 6. Student design work with the card-based design system (Fear Monitor App)

"*I was inspired to think of new ideas, by seeing all of the possible problems (red cards) and the technology (blue cards) that could detect such a problem at once*."

The participants found the collaboration during the design with the CBD tool is effective. As one participant stated:

"*Personally I also thought it was a great technology that I had never worked with before, but would love to use it more often for collaborative projects*."

One participant from another team also stated:

"*We collaborated very well and came up with an idea that we all agreed on. We managed to organize our thoughts with the picture cards fairly well too*."

In the study, the zooming gestures were observed being used by all groups (e.g. Figure 7). Besides making the card bigger to see the picture details, we found students use the zooming gesture to express semantic meanings. Some groups use the zooming gesture to indicate importance of a card. For example, in the design of word visualizer, the students zoomed the "Understand Words Worse than Pictures" card bigger to show that their technology solution was centered on that problem. Another use of the gesture is to capture partners' attention. For example, a student zoomed a card in the center of the display and explained his thought about that card.

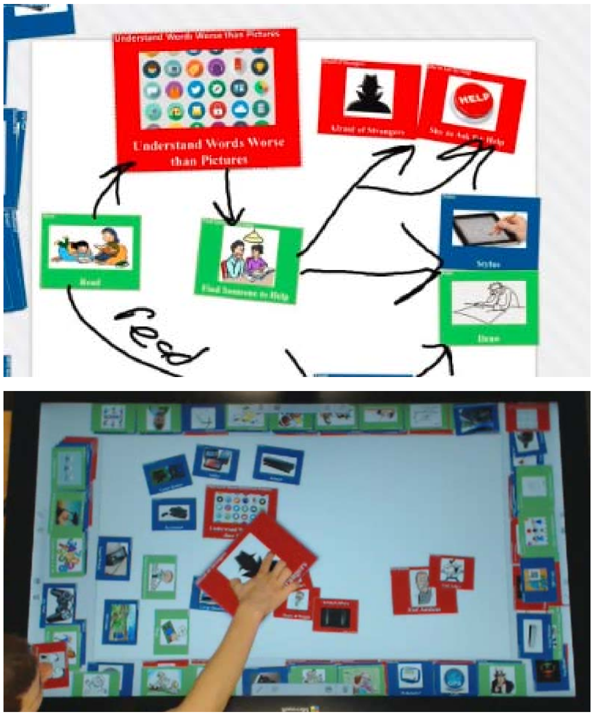

Figure 7. Using semantic zoom in the design.

We found the dynamic grouping is an important approach to help students find design inspiration. From our observation, tentative grouping of the cards attempt to describe new ideas or possibilities. These type of dynamic grouping activities increase the design ideas and expand the scope of thinking. But when the students clustering similar or highly related cards into a pile, they are trying to clarify the relationship between design elements or polish the final design ideas. In this case the dynamic grouping activity narrow down the design alternatives and help students come into a conclusion.

IX. DISCUSSION

Through the two empirical deployments of the MUMT system with K-8 students and college students, we discuss the knowledge gleaned from the observation on the creative and collaborative learning process. During our study, both age groups enjoyed the interaction with the MUMT display. The multi-user, multi-touch space served as a platform for students to explore the knowledge and exchange ideas. The knowledge exploration and idea generation activities observed from our study participants suggests that MUMT systems provides new pedagogical possibilities for the engaged learning.

Supporting different collaboration manners are essential to design digital learning tools. In both studies, students transition between quiet individual work and communicative group work. The older students are more engaged to collaborate with each other. When exploring and discovering new ideas with the digital cards, the college students tend to share ideas with others, and ask for agreement before making decisions. Those collaborative activities help students build common ground on the joint task and raise the motivation to explore more design possibilities. Though several students play at different sides of the table at the same time, young children are more likely to play the game individually. MUMT system designers should consider how to enhance young children’s collaborative behaviors while interacting with a shared multi-touch display. The collaborative behaviors with K-8 students include sharing the digital objects and teaching others how to play the cards. Other positive collaborative behaviors like “creating our new game” and “seeing what we can do” are also a source of creativity and inspiration. The conflicts happened in the game suggest that more efforts need to be made to solve the interferences of interaction during the simultaneous use of the display. This is especially important in a walk-up-and-use scenario, since young children are eager to play the game and taking turns to play the game might reduce their willingness to participate.

Semantic zooming as an intuitive and easy-to-understand interaction technique stimulates creativity and deliver ideas in the collaboration of our participants. The K-8 students found the gradually appeared content an interesting way to explore the digital content. The ambiguous appearance of the character raises the curiosity of the young children. The progressively appeared details encourage the exploration. The semantic zooming can be applied in other learning materials, e.g. showing a high-level definition of a knowledge at the beginning, and more explanations show up while the children zoom the material for details. In our study with the college students, the zooming gestures have more semantic and collaborative meanings. Important elements are in bigger size and digital cards are zoomed while student explain the ideas. This interaction metaphor can support better idea brainstorming and communication. Future system will consider providing more information while zooming a digital card, since more related information on an interested idea will scaffold understanding and communication.

Dynamic grouping is another source of creativity in our study with the college students. The students find new design possibilities by connecting and grouping the design materials together. Grouping the design cards is centrally important for creativity and idea specification. From our observation, examples of grouping activities vary widely, such as connecting a technology card to a problem card to find new ways to solve the problem, and connecting an activity card to a technology card to discover new manners of using the technology. These types of activities hold an important advantage in using the digital cards, as a card represents a lightweight form of element in the collaboration space which scaffolds fast association and organization. The many ways of connecting design cards greatly increases the number of possibilities in the design.

The info glow was intended to enhance collaborative behavior between young children. During the study we did not see intense use of the info glow by the children. We were hoping to see the children ask for consent before changing the background color, therefore increase the awareness politeness and collaboration. However, the children did not realize their behavior might change other’s digital object, and few children noticed the background change made by others. Beyond that children did not communicate a lot, another reason might be that the space is big and many characters are used at the same time, children paid more attention to other visual stimuli like zooming and card gliding. The background change is not very noticeable when other animations happened on the table. Other conflicts include zooming the object too big which interferes other's game, or fighting with each other for the same digital characters. Education software designers should not ignore the interference of interaction that might happen in the interaction with MUMT systems. Better collaborative interaction techniques and ways to coordinate the simultaneous use of the system should be considered. A MUMT-based education system will educate proper social behavior and help children build skills to collaborate.

X. Conclusion and Future Work

This paper presents our explorations investigating the usage of collaborative techniques based on a MUMT display, focusing on the impacts on three interaction techniques for educational goals and objectives. Two investigations of a card-based platform are conducted, and the findings and knowledge drawn from the investigations are discussed. The MUMT-based tool used in the investigation supports the inspiration of creativity and engagement in collaboration. It also facilitates the participants' collaboration and discovery of new ideas. The result of the investigation shows that college students tend to engage more with others, while young children would like to play with the interactive table individually. The digital cards used in the study helped college-level participants generate ideas and identify relationships

Semantic zooming is an interaction technique to facilitate knowledge exploration and transition. It encourages young students to explore the content, and for older students it serves as a way to emphasize and communicate ideas. Dynamic grouping is an important way for older students to generate and specify inspiration. Trying out different combinations of the cards gives college students many new ideas. Info glow is a design to show the changes made by others, but young children are easily to ignore it since the children did not communicate a lot while playing the game. Other interaction and animation may also make them hard to find.

With the lessons learned in this study, we suggest the following guidelines for building, selecting or using a MUMT system for education. First, it should be easy for students to browse the digital content, while simultaneously supporting idea inspiration and collaboration. For example, the gradually appearing content when the digital items are enlarged has promise to help students in exploring and communicating ideas, as well as in assisting the team in keeping aware of the candidate ideas. Further, the digital cards should be flexible enough in supporting diverse ways of combination to highlight idea alternatives. This will expand the possibilities and therefore enhance the creativity. The methods to create these groups should also be carefully designed, as an easy and fast method to specify the element relationships will not only improve the design efficiency, but also clarify and unify the idea into a more integrated style. Better ways to deliver the information about the recent changes need to be considered, and the conflicts and interferences during the simultaneous interaction need to be addressed.

Building on the knowledge gleaned from this study, future work should probe the role of different methods and technologies with MUMT display in raising creativity and enhancing collaboration. The ways in which the notifications about the recent changes made by others are delivered and received will also be explored in future study. Other efforts to promote using the MUMT displays in engaged learning include using the interaction techniques probed in this study, like semantic zoom and dynamic grouping, in real classroom settings.

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