Supporting school group visits to fine arts museums in the 21st century: A CSCL concept for a multi-touch table based video tool

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Abstract: School visits to art museums are a vital aspect of art education and cultural participation. In this paper we present a CSCL concept designed to encourage students to observe closely and reflect on art works in art museums. The concept is based on a multilevel perspective on learning in art museums. It is implemented by means of a multi-touch tabletop and a video tool with functions enabling students to collaborate on processing digital reproductions of art works in small groups during a collaborative visual design task.

Introduction

Visits to arts museums and exhibitions are a vital aspect of arts education and cultural participation (for indicators of cultural participation, see Morrone, 2006). School visits to arts museums provide access to arts and high culture for a broad range of children and youth – including those coming from family backgrounds where parents are not able to or not interested in visiting fine arts museums. Hence, school museum visits are considered particularly suitable occasions for framing participation in public spaces (Nespor, 2000).

School visits are supported by museums in various ways – be it free entrance for school groups, special guided tours, or high quality educational services for K–12 educators on museum webpages. For example, The Metropolitan Museum of Art (NY) offers among other services detailed topic-specific lesson plans that relate explicitly to the National Visual Arts Standards and comprise suggestions for advanced learning activities to explore and reflect on art objects in the museum's collections (1).

Targeting the intersection of museum and school education, we propose in this paper a CSCL concept to support analysis and interpretation of art works during school visits to fine arts museums. Specifically, we investigate a concept that fosters students' close observation and reflection of art works, while sustaining the experiential flavor of the museum visit (cf. Duke, 2010). It is implemented by means of a multi-touch tabletop (MTT) and a video tool for collaborative visual design tasks in small groups. The concept has been developed through close interdisciplinary cooperation of psychologists, computer scientists and museum educators. Our work is based on our previous CSCL research which shows that advanced digital technologies offer specific opportunities for fostering knowledge construction and learning during *collaborative design activities* (e.g., Zahn, Pea, Hesse, & Rosen, 2010) and for *knowledge communication in museums* (Knipfer, Mayr, Zahn, Schwan, & Hesse, 2009). It is also firmly rooted in related CSCL perspectives, assuming multiple levels of learning ranging from individuals to communities, and assuming small group interaction to be the primary unit that mediates between individual learning and community learning (Engeström, 1999; G. Stahl, Koschmann, & Suthers, 2006; G. Stahl, 2006). In the following sections we will describe the theoretical and technical underpinnings of our concept. We will first review curricular and museum educational requirements. Subsequently, we will elaborate on how the collaborative visual design approach backed by MTT hardware can meet these requirements. The tool's implementation and functionality will be described thereafter.

Theoretical Framework

K–12 visual art education and museum educational goals

Among the most important skills which should and can be learned in visual art education, are the analysis and interpretation of visual material (National Art Education Association, 1994; Winner, 2007). In this respect, Winner (2007) differentiates between *observation* and *reflection*. Observation encompasses attending to aspects and details of works of art, especially when they are not obvious. Reflection refers to activities such as questioning, explaining and evaluating one's own works and those of others (Winner, 2007). For example, students may "explain *what* some part of their drawing depicted, *how* they had achieved a certain effect, *why* they had made something the way they did, and *what* changes they were planning in their work" (Winner, 2007, p. 28; italics in original). In addition to these academic learning objectives, museum educators stress the point that the museum visit provides an opportunity to have unique (aesthetic) experiences (cf. Pekarik, Doering, &

Karns, 1999) and to learn from those experiences beyond the "right answer paradigm" (Duke, 2010, p. 271). In this way, Barrett (2008) emphasizes the importance of multi-perspectivity in the interpretation of works of art. Such a constructivist approach to museum education is in line with the current trend toward shifting interpretative power from authorities like curators and art historians to the common visitors (cf. Barrett, 2008; Hooper-Greenhill, 2000; Trant, 2006). In the specific case of school group visits, the goals of academic visual arts education and museum education coincide in a collaborative learning situation. The specific challenge is to support such collaborative learning in fine arts exhibitions showing inestimable and untouchable (!) original art works.

We argue here from a CSCL perspective that advanced media applications in museums are suitable for supporting close observation and reflection, as well as active and collaborative learning (cf. Knipfer et al., 2009). More specifically, we argue that learning through *collaborative visual design* with digital video tools is a promising approach for meeting those requirements in a fine arts museum. In the following sections we will explain why.

Supporting observation and reflection in the art museum – a CSCL concept

Building on CSCL theory (e.g., Engeström, 1999; G. Stahl et al., 2006; G. Stahl, 2006), we develop our concept for school class visits in a fine arts museum according to the following framework:

We assume a multilevel structure of observation and reflection in a museum environment distinguishing five levels: (i) a cognitive level, where observation and reflection of art works is performed by the individual student in front of an original art work in "silent dialogue", guided by individual knowledge and information processing abilities (cf. Leder, Belke, Oeberst, & Augustin, 2004). (ii) a socio-cognitive level, where observation and reflection is a collaborative activity of two or more students engaging in what Pea (2006, p. 1332) termed the "look-notice-comment cycle (LNC)" – the iterative sequence of observing, directing another person's attention and commenting (Pea, 2006). In these cycles, one person's observation becomes the starting point for a discussion, which in turn leads to further discoveries and interpretations by other group members and so forth. (iii) a socio-constructivist or: small group level, where the whole process of the students' joint observation and reflection is held and supported by a task structure, which transforms those processes into a lasting artifact, mediated by technological affordances (cf. Suthers & Hundhausen, 2003). (iv) a class level, where observation and reflection and their manifestation in students' group products (artifacts) form a collective museum experience that is guided by curricular goals and standards (cf. National Art Education Association, 1994) and moderated by the teacher. (v) a socio-cultural or: community level, where observation and reflection consist of a museum's contextualized activities for knowledge building (Scardamalia, 2002), e.g., collecting, storing and presenting art works as cultural heritage, and providing for constant dialogues between artists and viewers/visitors mediated by expert curators.

We assume the five levels in our art educational concept for school class visits in a fine arts museum as being connected by *small group student interaction*. In accordance with related CSCL research, we thus put small groups at the core of the concept: Small group interaction is the primary unit that mediates between the multiple levels ranging from individual learning to community learning (G. Stahl et al., 2006; G. Stahl, 2006). Specifically, we suggest that learning through *collaborative visual design* (Zahn, Krauskopf, Hesse, & Pea, 2010) is a task that connects individual cognition to participation in knowledge building (Zahn, Krauskopf, Hesse, & Pea, 2009). By accomplishing design tasks together, students are cognitively active, they collaborate and they produce new knowledge products for the community – thereby deepening their own knowledge and adding to the community knowledge. Moreover, collaborative visual design is in line with curricular and museum educational needs: It is suitable for fostering observation and reflection skills and – as a constructivist approach – it is capable of sustaining the experiential flavor of the museum visit.

In order to allow students to learn through collaborative visual design in the art museum of the 21st century, it is crucial to provide for hardware and software solutions, which are not only appropriate for the task (cf. Pea, 2006; Zahn, Pea, et al., 2010) but also meet the special requirements of a museum environment (cf. Hinrichs, Schmidt, & Carpendale, 2008; Jacucci et al., 2010). In search of appropriate hardware that can support a collaborative design task in the museum, we explore the potential of MTTs, which have already made their way into many museums. In terms of software, we rely on digital video tools that have a tradition of being used for observation and analysis skills development, including those from our own research (e.g., Goldman, 2004, 2007; Pea, 2006; Salomon, 1974; Spiro, Coulson, Feltovich, & Anderson, 1994; Zahn, Pea, et al., 2010).

Providing task structures for school group visits: Learning through collaborative visual design

Our concept builds on the learning through collaborative design approach for small groups of students (similar to *learning through design*, Kafai & Resnick, 1996). For decades, computer supported design tasks have been successfully implemented in schools (Harel, 1990; Kafai & Ching, 2001; Kafai & Resnick, 1996; Kolodner et al., 2003; Lehrer, Erickson, & Connell, 1994; Papert & Harel, 1991). Studies investigating collaborative visual design tasks in the domain of history have repeatedly shown how students acquire substantial historical knowledge and visual skills when they design websites for a virtual history museum, using a historical newsreel and advanced video editing tools in their history lesson (Zahn, Krauskopf, et al., 2010; Zahn, Pea, et al., 2010). The conceptual underpinnings of the collaborative visual design approach have been described in earlier CSCL, JLS and iJCSCL papers (Zahn, Pea, et al., 2010; Zahn et al., 2005; Zahn, Krauskopf, Hesse, & Pea, 2011, 2012). The basic assumption is that visual design leads to a deep and meaningful engagement with content, since it links people, form and content in a combined design space. People engaging in a collaborative design task have to negotiate not only the content (what should be designed) but also the form (how it should be designed for a specific audience; cf. Harel, 1990; Kafai & Ching, 2001), while coordinating their collaborative process at the same time (Zahn et al., 2012). In this sense, collaborative design constitutes a form of complex problem solving that is distributed over the cognitive systems of different people in a joint problem space (Zahn, Krauskopf, et al., 2010; cf. Roschelle & Teasley, 1995).

Providing digital tools with socio-constructivist potential: Multi-touch tabletop technology

Our concept includes the use of a multi-touch tabletop system (see Figure 1). Multi-touch tabletops are horizontal displays that allow simultaneous interaction of several people by touch input (Harris et al., 2009). They have received a lot of attention recently – not only by museums around the world, which incorporate MTTs in their visitor information systems and exhibits (e.g., Correia, Mota, Nóbrega, Silva, & Almeida, 2010; Geller, 2006; Hornecker, 2008), but also from the CSCL community (cf. Dillenbourg & Evans, 2011; Higgins, Mercier, Burd, & Hatch, 2011): MTTs are assumed to afford a more collaborative and constructivist working mode, thereby favorably suited for learning activities (cf. Kaplan et al., 2009). Dillenbourg & Evans (2011, p. 491) have characterized this as the "socio-constructivist flavor" of tabletops. The authors identify four key features, which may set MTTs apart from other computing devices in terms of their potential as learning tools: MTTs are designed for (i) co-located (ii) multiple users, who interact with each other via (iii) multiple forms of communication (i.e. gestures, talk, and actions), while primarily engaging in (iv) hands-on problem solving activities (i.e. manipulation of virtual objects). Building on this socio-constructivist potential and their increasing availability in museums, we consider MTTs to be promising candidates as tools for learning through visual design in museum art education. As a matter of fact, MTTs have already been used as a basis for design and video editing tasks (e.g., de Sa, Shamma, & Churchill, 2012; Rick, Rogers, Haig, & Yuill, 2009; Warnecke, Dohrmann, Jürgens, Rausch, & Pinkwart, 2011). However, as Dillenbourg & Evans (2011, p. 500) point out, although the medium may lend itself to a certain use, the technology itself does not have any "intrinsic pedagogical effects". Whether or not a device can be utilized as an effective learning tool depends mainly on the respective task and on the conditions of its usage. As we intend to illustrate below, learning through collaborative visual design offers a framework that allows for meaningful tasks which make full use of the MTTs' socio-constructivist potential.

Providing digital tools to support observation, analysis and reflection

Research in the learning sciences has provided ample evidence for using digital video technology to support a variety of socio-cognitive functions. Since early research on the educational value of films, where Salomon (1974) found that filmic coding elements can facilitate individual students' mastery of mental skills necessary to attend to details of art works, video was repeatedly suggested as a tool for observation, analysis and reflection (Goldman, 2004, 2007; Pea, 2006; Pea et al., 2004; Spiro et al., 1994). It was shown in experiments how different video tools influence collaborative epistemic activities (grounding, negotiation, comparison and interpretation processes) for students using those video tools (e.g., Zahn, Pea, et al., 2010): Results from different studies show that the affordances of specific video tools (e.g., WebDiver™, Pea et al., 2004) better support learners' interactions in making them more productive, compared to interactions performed with simple technological solutions. The results were improvements in learning outcomes and observation abilities (Zahn, Pea, et al., 2010). A field study further revealed that the differences in learners' interactions persist in the real, "noisy" history classroom with 16-year old students (e.g., Zahn, Krauskopf, et al., 2010). In these studies it was the student's task, to design a website for a virtual history museum, based on their analysis and decomposition of an original newsreel about the 1948 Berlin Blockade. In their products, the students reflected and commented upon the different camera and cutting techniques and the respective effects that these techniques evoked. Yet there are no studies available concerning the use of advanced video tools in art education or in art museums.

Learning through collaborative visual design in the art museum

The task concept

Derived from our multilevel CSCL framework, we have developed the following task structure: During a school visit, students individually browse the museum's collection (cognitive level, see above), guided by an art educational group task (for possible tasks see scenario below and table 1), and collect digital reproductions of art works from the museum space (community level) using smartphones. The reproductions then can be transferred to the MTT and processed by means of a video tool in order to produce a video clip in each group (socio-constructivist or small group level, see above). Thereby, students discuss with other students, which reproductions should be selected and how they should be further processed in the video clip production (socio-cognitive level). The clip will eventually be saved, which enables classmates, teachers or other people to share, discuss and enrich the product (class and community level).

In the next section, we will elaborate more deeply on how students will be supported during video clip production through socio-cognitive tool functions. The task workflow is depicted in Figure 1. For details regarding the general design task structure please refer to Zahn, Krauskopf, Hesse, & Pea (2010).

Implementation of socio-cognitive functions in the MTT video editing tool

We implemented specific video functions to support observation and reflection (socio-cognitive level, see above). The video functions consist of three basic socio-cognitive functions that are based on related research in cognitive psychology and the learning sciences: counterfactual image manipulations, highlighting of aspects within images, and linking images to create sequences. All functions constitute epistemic actions, as described by Kirsh and Maglio (1994). *Counterfactual image manipulations* are image modifications based on digital imaging filters, which change an image's formal appearance; for instance, a painting's strong light and dark contrasts can be changed to more subtle lighting differences and vice versa (see example scenario below). Counterfactual image manipulations were implemented in accordance with the concept of counterfactual thinking (e.g., Byrne, 2005) and the understanding of manipulations as cues to causality (cf. Woodward, 2005). We assume the following: Because generating mental alternatives to reality (counterfactual thinking) can assist people in thinking about the causes of effects and events (causal reasoning; e.g., Spellman & Mandel, 1999), creating alternatives to visual material (counterfactual image manipulations) can help to reflect upon the causes of certain visual effects. We implement a tool based strategy here, since it can be difficult to mentally manipulate a painting (i.e. to create a counterfactual painting; cf. Brandimonte, Hitch, & Bishop, 1992; Chambers & Reisberg, 1985). So far, four specific image filters have been implemented in our tool: Saturation, lightness, color temperature and vertical orientation (reversal of left/right orientation). For possible filter uses see Table 1. *Highlighting* is a well-known function that helps to bring out specific features of (visual) information. This function has already been investigated in detail with respect to arts education (cf. Salomon, 1974) and implemented in video analysis tools (Pea et al., 2004). Figure 1e shows an example of a highlighting function: An important detail of an art work is marked by a freehand drawing tool. Other planned functions contain spotlight, zoom and text annotation functionalities. *Linking images* to create new sequences is a tool function known from hypertext and hypervideo tools research in the learning sciences (Spiro & Jehng, 1990; E. Stahl & Bromme, 2004; Zahn & Finke, 2003). In our tool, reproductions of paintings can be linked to compose a slideshow, thereby facilitating, for example, comparisons regarding content, epoch, style and artist. For instance, the linking function offers a convenient way to tell the history of portrait painting or to give an overview of variations on the same motif throughout different epochs. The activity of linking images creates (new) connections among them. We assume that this leads to mental integration and, finally, to building respective knowledge structures.

According to our CSCL concept for supporting school visits to art museums, and as a basis for further research, we develop example learning scenarios in cooperation with a fine arts museum in Germany (2).

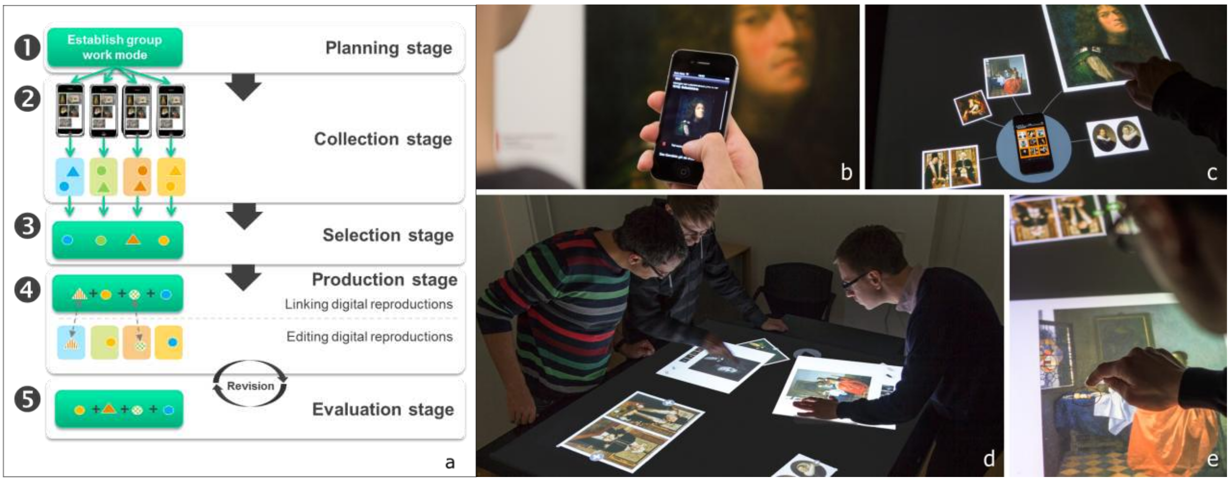

Figure 1. Task workflow (a; see also Zahn, Krauskopf, et al., 2010) and tool functions for collaborative visual design in a fine arts museum: Collecting digital reproductions in the museum via smartphones (b). Selecting collected reproductions from the smartphone at the MTT (c). Processing digital reproductions collaboratively at the MTT (d). Detail view of a highlighting function (drawing a circle around an important detail) (e).

Example Scenario: Light and Shadow

Let's say that an advanced art class visits a fine arts museum in order to study the effects of different light-shadow techniques. In order to learn about the use of light in art, the teacher asks the arts class to accomplish a collaborative visual design task to compare the effects of strong light-dark contrasts (a technique known as chiaroscuro) to more subtle light-dark contrasts. Students are divided into two groups. Each group will be encouraged to focus on one technique (chiaroscuro vs. subtle contrasts) and to "collect" digital reproductions of appropriate art works with smartphones while browsing the museum's exhibition (see 1b). After returning to the MTT, the students can transfer their collected art works to the MTT and discuss in small groups which of them should be included in the video clip (see Figure 1c). Following this selection phase, the students will start the video editing (cf. Figure 1e). They use different image filters in order to find out how the appearance and the art work's effect will change due to alteration of contrast and lightness: Shifting an image towards a strong light-dark contrast evokes a chiaroscuro with dramatic appeal, while a reduction creates the opposite effect. If necessary, images can be annotated with short texts. Parallel to the editing, the students can decide on the sequence (cf. Figure 1d) in which the art works will be presented within the clip. A playback function enables the users to preview and revise their work. Subsequent to the editing phase, the students can save the clip. Finally, the clip will be made accessible through the museum's website and can be used for further discussion in class. The described scenario is just one example, for other possible applications please refer to Table 1. Also please note: The examples provide only a basis for supporting teachers and museum staff, who will decide on how the tool will be integrated in a particular school visit. Under ideal conditions, a specific learning scenario could be prepared in class, played out in the museum using the MTT and reinforced, again, in class. Art teachers can also invent different tool-based scenarios, which allow for a more spontaneous use of the tool on-site. Moreover – after careful reviewing by museum staff – successful user-generated scenarios will be provided at the MTT for other visitors, thereby establishing a scenario database to be used in the long run.

Table 1. Examples for topics and possible scenarios supported by MTT and video editing tool.

Topic	Possible scenario and technology support (MTT video editing)
Light and shadow	Students tell the history of shadow depiction in visual art (cf. Gombrich, 1995) in a video clip, or they illustrate the difference between cast and attached shadows (cf. Jacobson & Werner, 2004) with different reproductions.
Details/Motifs	Students look out for art works with interesting but less obvious details (e.g., symbols, motifs). They collect them and use highlighting functions to bring out the details in digital reproduction of the art works. By linking images in a slideshow, students recognize the same motif in art works across different artists, styles, epochs etc.
Composition	Students identify the compositional structure of a painting: They test hypotheses regarding the composition by sketching overlays directly on the reproduction. By flipping reproductions horizontally, students can learn about the importance of left-right orientation in paintings (cf. Bennett, Latto, Bertamini, Bianchi, & Minshull, 2010; Zaidel & Fitzgerald, 1994).
Color	Students collect reproductions of particular warm and cold colored paintings and discuss how a change in color temperature affects the impression and meaning of these paintings.

Discussion and Outlook

In this paper we have presented a multilevel CSCL concept for learning through collaborative visual design with an MTT based advanced video editing tool that can be adopted in fine arts museums to foster the observation and reflection required in academic art education. Our concept constitutes a method that can be tailored to further topics and learning objectives. Although the learning through visual design method is empirically validated, the present concept warrants further research: In a next step we intend to investigate the concept and the tool within a sample scenario. For further experimental research, multilevel approaches will be considered. Notwithstanding future research, in our view the concept proposed in this paper offers at least three advantages for museum and curricular art education: (i) Museums and schools are both social places which serve an educational purpose – our CSCL concept can account for that fact by supporting "21st century collaborative learning". (ii) The educational concept meets both curricular and museum educational requirements. It complements other art educational strategies and is highly adaptable to specific learning goals. (iii) Building on the high popularity of interactive displays among young adults (cf. nielsenwire, 2012), the present concept may help to bridge the gap between young students and old masters through new media. However, some curators are concerned that digital media could actually hinder appropriate art appreciation. Since this concern is justified in certain cases (cf. Hsi, 2003), it should be deliberated whether the use of a certain technology offers an added value (cf. Buder, 2007). As original paintings cannot be altered, annotated or even viewed from close distances, we consider the added value of our video tool to be evident. Furthermore, our task ensures a close relationship between digital reproductions and original art works.

Endnotes

(1) http://www.metmuseum.org/en/learn/for-educators/lesson-plans-and-pre-visit-guides
(2) Herzog Anton Ulrich-Museum, Braunschweig, Germany.

References

Barrett, T. (2008). Interactive Touring in Art Museums: Constructing Meanings and Creating Communities of Understanding. *Visual Arts Research*, *34*(2(67)), 76–84.

Bennett, K. M., Latto, R., Bertamini, M., Bianchi, I., & Minshull, S. (2010). Does left-right orientation matter in the perceived expressiveness of pictures? A study of Bewick's animals (1753-1828). *Perception*, *39*(7), 970–981.

Brandimonte, M. A., Hitch, G. J., & Bishop, D. V. M. (1992). Manipulation of visual mental images in children and adults. *Journal of Experimental Child Psychology*, *53*(3), 300–312. doi:10.1016/0022-0965(92)90041-4

Buder, J. (2007). Net-Based Knowledge Communication in Groups. *Zeitschrift für Psychologie / Journal of Psychology*, *215*(4), 209–217. doi:10.1027/0044-3409.215.4.209

Byrne, R. M. J. (2005). *The Rational Imagination: How People Create Alternatives To Reality*. Cambridge, MA, US: MIT Press.

Chambers, D., & Reisberg, D. (1985). Can mental images be ambiguous? *Journal of Experimental Psychology: Human Perception and Performance*, *11*(3), 317–328. doi:10.1037/0096-1523.11.3.317

Correia, N., Mota, T., Nóbrega, R., Silva, L., & Almeida, A. (2010). A multi-touch tabletop for robust multimedia interaction in museums. In *Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces 2010* (pp. 117–120). New York, NY, US: ACM.

De Sa, M., Shamma, D., & Churchill, E. (2012). Live Mobile Collaboration for Video Production: Design, Guidelines, and Requirements. *Personal and Ubiquitous Computing*.

Dillenbourg, P., & Evans, M. (2011). Interactive tabletops in education. *International Journal of Computer-Supported Collaborative Learning*, *6*(4), 491–514. doi:10.1007/s11412-011-9127-7

Duke, L. (2010). The Museum Visit: It's an Experience, Not a Lesson. *Curator: The Museum Journal*, *53*(3), 271–279. doi:10.1111/j.2151-6952.2010.00028.x

Engeström, Y. (1999). Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen, & R.-L. Punamäki (Eds.), *Perspectives on Activity Theory* (pp. 19–38). Cambridge, UK: Cambridge University Press.

Geller, T. (2006). Interactive Tabletop Exhibits in Museums and Galleries. *IEEE Computer Graphics and Applications*, *26*(5), 6–11.

Goldman, R. (2004). Video perspectivity meets wild and crazy teens: a design ethnography. *Cambridge Journal of Education*, *34*(2), 157–178. doi:10.1080/03057640410001700543

Goldman, R. (2007). Video Representations and the Perspectivity Framework: Epistemology, Ethnography, Evaluation, and Ethics. In R. Goldman, R. Pea, B. Barron, & S. J. Derry (Eds.), *Video research in the learning sciences* (pp. 3–36). Mahwah, NJ, US: Lawrence Erlbaum Associates.

Gombrich, E. H. (1995). *Shadows: The Depiction of Cast Shadows in Western Art*. London: National Gallery Company Ltd.

Harel, I. (1990). Children as Software Designers: A Constructionist Approach for Learning Mathematics. *Journal of Mathematical Behavior*, *9*(1), 3–93.

Harris, A., Rick, J., Bonnett, V., Yuill, N., Fleck, R., Marshall, P., & Rogers, Y. (2009). Around the table: Are multiple-touch surfaces better than single-touch for children's collaborative interactions? In *Proceedings of the 9th international conference on Computer supported collaborative learning* (pp. 335–344). ISLS.

Higgins, S. E., Mercier, E., Burd, E., & Hatch, A. (2011). Multi-touch tables and the relationship with collaborative classroom pedagogies: A synthetic review. *International Journal of Computer-Supported Collaborative Learning*, *6*(4), 515–538. doi:10.1007/s11412-011-9131-y

Hinrichs, U., Schmidt, H., & Carpendale, S. (2008). EMDialog: Bringing Information Visualization into the Museum. *IEEE Transactions on Visualization and Computer Graphics*, *14*(6), 1181 –1188. doi:10.1109/TVCG.2008.127

Hooper-Greenhill, E. (2000). Changing Values in the Art Museum: rethinking communication and learning. *International Journal of Heritage Studies*, *6*(1), 9–31. doi:10.1080/135272500363715

Hornecker, E. (2008). "I don't understand it either, but it is cool" - visitor interactions with a multi-touch table in a museum. In *TABLETOP 2008: Proceedings of IEEE International Workshop on Horizontal Interactive Human Computer Systems* (pp. 113–120). Amsterdam, the Netherlands: IEEE.

Hsi, S. (2003). A study of user experiences mediated by nomadic web content in a museum. *Journal of Computer Assisted Learning*, *19*(3), 308–319. doi:10.1046/j.0266-4909.2003.jca_023.x

Jacobson, J., & Werner, S. (2004). Why cast shadows are expendable: Insensitivity of human observers and the inherent ambiguity of cast shadows in pictorial art. *Perception*, *33*(11), 1369–1383. doi:10.1068/p5320

Jacucci, G., Morrison, A., Richard, G. T., Kleimola, J., Peltonen, P., Parisi, L., & Laitinen, T. (2010). Worlds of information: designing for engagement at a public multi-touch display. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2267–2276). New York, NY, US: ACM. doi:10.1145/1753326.1753669

Kafai, Y. B., & Ching, C. C. (2001). Affordances of Collaborative Software Design Planning for Elementary Students' Science Talk. *Journal of the Learning Sciences*, *10*, 323–363. doi:10.1207/S15327809JLS1003_4

Kafai, Y. B., & Resnick, M. (1996). *Constructionism in Practice: Designing, Thinking, and Learning in A Digital World*. Mahwah, NJ, US: Routledge.

Kaplan, F., DoLenh, S., Bachour, K., Kao, G. Y., Gault, C., & Dillenbourg, P. (2009). Interpersonal Computers for Higher Education. In P. Dillenbourg, J. Huang, & M. Cherubini (Eds.), *Interactive Artifacts and Furniture Supporting Collaborative Work and Learning* (Vol. 10, pp. 1–17). New York, NY, US: Springer.

Kirsh, D., & Maglio, P. (1994). On distinguishing epistemic from pragmatic action. *Cognitive Science*, *18*(4), 513–549. doi:10.1016/0364-0213(94)90007-8

Knipfer, K., Mayr, E., Zahn, C., Schwan, S., & Hesse, F. W. (2009). Computer support for knowledge communication in science exhibitions: Novel perspectives from research on collaborative learning. *Educational Research Review*, *4*, 196–209. doi:10.1016/j.edurev.2009.06.002

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., … Ryan, M. (2003). Problem-Based Learning Meets Case-Based Reasoning in the Middle-School Science Classroom: Putting Learning by Design™ into Practice. *The Journal of the Learning Sciences*, *12*(4), 495–547.

Leder, H., Belke, B., Oeberst, A., & Augustin, D. (2004). A model of aesthetic appreciation and aesthetic judgments. *British Journal of Psychology*, *95*(4), 489–508. doi:10.1348/0007126042369811

Lehrer, R., Erickson, J., & Connell, T. (1994). Learning by designing hypermedia documents. *Computers in the Schools*, *10*(1-2), 227–254. doi:10.1300/J025v10n01_15

Morrone, A. (2006). *Guidelines for measuring cultural participation*. Montreal, Quebec, Canada: UNESCO Institute for Statistics.

National Art Education Association. (1994). *The National Visual Arts Standards.* Reston, VA, US: National Art Education Association.

Nespor, J. (2000). School field trips and the curriculum of public spaces. *Journal of Curriculum Studies*, *32*(1), 25–43. doi:10.1080/002202700182835

nielsenwire. (2012, February 23). Introducing Generation C: Americans 18-34 Are the Most Connected. Retrieved from http://blog.nielsen.com/nielsenwire/online_mobile/introducing-generation-c/

Papert, S., & Harel, I. (1991). Situating Constructionism. In S. Papert & I. Harel (Eds.), *Constructionism*. Norwood, NJ, US: Ablex Publishing Corporation.

Pea, R. (2006). Video-as-Data and Digital Video Manipulation Techniques for Transforming Learning Sciences Research, Education, and Other Cultural Practices. In J. Weiss, J. Nolan, J. Hunsinger, & P. Trifonas (Eds.), *The International Handbook of Virtual Learning Environments* (pp. 1321–1393). Dordrecht, the Netherlands: Springer.

Pea, R., Mills, M., Rosen, J., Dauber, K., Effelsberg, W., & Hoffert, E. (2004). The Diver project: interactive digital video repurposing. *IEEE MultiMedia*, *11*(1), 54 – 61. doi:10.1109/MMUL.2004.1261108

Pekarik, A. J., Doering, Z. D., & Karns, D. A. (1999). Exploring Satisfying Experiences in Museums. *Curator: The Museum Journal*, *42*(2), 152–173. doi:10.1111/j.2151-6952.1999.tb01137.x

Rick, J., Rogers, Y., Haig, C., & Yuill, N. (2009). Learning by doing with shareable interfaces. *Children, Youth and Environments*, *19*(1), 321–342.

Roschelle, J., & Teasley, S. D. (1995). The construction of shared knowledge in collaborative problem solving. In C. O'Malley (Ed.), *Computer supported collaborative learning* (Vol. 128, pp. 69–97). Germany: Springer.

Salomon, G. (1974). Internalization of filmic schematic operations in interaction with learners' aptitudes. *Journal of Educational Psychology*, *66*(4), 499–511. doi:10.1037/h0036753

Scardamalia, M. (2002). Liberal Education in a Knowledge Society. In B. Smith (Ed.), *Collective Cognitive Responsibility for the Advancement of Knowledge* (pp. 67–98). Peru, Illinois, US: Open Court Publishing.

Spellman, B. A., & Mandel, D. R. (1999). When Possibility Informs Reality. Counterfactual Thinking as a Cue to Causality. *Current Directions in Psychological Science*, *8*(4), 120–123. doi:10.1111/1467-8721.00028

Spiro, R. J., Coulson, R. L., Feltovich, P. J., & Anderson, D. K. (1994). Cognitive flexibility theory: Advanced knowledge acquisition in ill-structured domains. In R. B. Ruddell, M. R. Ruddell, & H. Singer (Eds.), *Theoretical models and processes of reading (4th ed.)* (pp. 602–615). Newark, DE, US: International Reading Association.

Spiro, R. J., & Jehng, J.-C. (1990). Cognitive flexibility and hypertext: Theory and technology for the nonlinear and multidimensional traversal of complex subject matter. In D. Nix & R. J. Spiro (Eds.), *Cognition, education, and multimedia: Exploring ideas in high technology* (pp. 163–205). Hillsdale, NJ, England: Lawrence Erlbaum Associates, Inc.

Stahl, E., & Bromme, R. (2004). Learning by Writing Hypertext: A Research Based Design of University Courses in Writing Hypertext. In G. Rijlaarsdam, H. Bergh, & M. Couzijn (Eds.), *Effective Learning and Teaching of Writing* (Vol. 14, pp. 547–559). Dordrecht, the Netherlands: Springer.

Stahl, G. (2006). *Group Cognition: Computer Support for Building Collaborative Knowledge*. Cambridge, MA, US: MIT Press.

Stahl, G., Koschmann, T., & Suthers, D. D. (2006). Computer-supported collaborative learning: An Historical Perspective. In R. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 409–426). Cambridge University Press.

Suthers, D. D., & Hundhausen, C. D. (2003). An Experimental Study of the Effects of Representational Guidance on Collaborative Learning Processes. *Journal of the Learning Sciences*, *12*(2), 183–218. doi:10.1207/S15327809JLS1202_2

Trant, J. (2006). Exploring the potential for social tagging and folksonomy in art museums: Proof of concept. *New Review of Hypermedia and Multimedia*, *12*(1), 83–105. doi:10.1080/13614560600802940

Warnecke, T., Dohrmann, P., Jürgens, A., Rausch, A., & Pinkwart, N. (2011). Collaborative Learning through Cooperative Design Using a Multitouch Table. In Y. Luo (Ed.), *Cooperative Design, Visualization, and Engineering* (Vol. 6874, pp. 22–29). Germany: Springer.

Winner, E. (2007). Visual thinking in arts education: Homage to Rudolf Arnheim. *Psychology of Aesthetics, Creativity, and the Arts*, *1*(1), 25–31. doi:10.1037/1931-3896.1.1.25

Woodward, J. (2005). *Making Things Happen: A Theory of Causal Explanation*. New York, NY, US: Oxford University Press.

Zahn, C., & Finke, M. (2003). Collaborative knowledge building based on hyperlinked video. In B. Wasson, R. Baggetun, U. Hoppe, & S. Ludvigsen (Eds.), *Proceedings of the International Conference on Computer Support for Collaborative Learning - CSCL 2003, COMMUNITY EVENTS - Communication and Interaction* (pp. 173–175). Bergen, NO: InterMedia.

Zahn, C., Hesse, F., Finke, M., Pea, R., Mills, M., & Rosen, J. (2005). Advanced digital video technologies to support collaborative learning in school education and beyond. In *Proceedings of th 2005 conference on Computer support for collaborative learning: learning 2005: the next 10 years!* (pp. 737–742). International Society of the Learning Sciences.

Zahn, C., Krauskopf, K., Hesse, F. W., & Pea, R. (2009). Participation in knowledge building "revisited": reflective discussion and information design with advanced digital video technology. In *Proceedings of the 9th international conference on Computer supported collaborative learning - Volume 1* (pp. 596–600). International Society of the Learning Sciences.

Zahn, C., Krauskopf, K., Hesse, F. W., & Pea, R. (2010). Digital video tools in the classroom: How to support meaningful collaboration and critical advanced thinking of students? In M. S. Khine & I. M. Saleh (Eds.), *New Science of Learning: Cognition, Computers and Collaboration in Education* (pp. 503–523). New York, NY, US: Springer.

Zahn, C., Krauskopf, K., Hesse, F. W., & Pea, R. (2011). Digital Media in the Classroom: A Study on How to Improve Guidance for Successful Collaboration and Learning in Student Teams. In H. Spada, G. Stahl, N. Miyake, & N. Law (Eds.), *Connecting Computer-Supported Collaborative Learning to Policy and Practice: CSCL2011 Conference Proceedings.* (Vol. 1, pp. 152–159). Hong Kong: International Society of the Learning Sciences.

Zahn, C., Krauskopf, K., Hesse, F. W., & Pea, R. (2012). How to improve collaborative learning with video tools in the classroom? Social vs. cognitive guidance for student teams. *International Journal of Computer-Supported Collaborative Learning*, *7*(2), 259–284. doi:10.1007/s11412-012-9145-0

Zahn, C., Pea, R., Hesse, F. W., & Rosen, J. (2010). Comparing Simple and Advanced Video Tools as Supports for Complex Collaborative Design Processes. *Journal of the Learning Sciences*, *19*(3), 403–440. doi:10.1080/10508401003708399

Zaidel, D. W., & Fitzgerald, P. (1994). Sex of the face in Western art: Left and right in portraits. *Empirical Studies of the Arts*, *12*(1), 9–19.

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