Handbook of Research on Maximizing Cognitive Learning through Knowledge Visualization

Anna Ursyn
University of Northern Colorado, USA

A volume in the Advances in Knowledge Acquisition, Transfer, and Management (AKATM) Book Series

Information Science REFERENCE
An Imprint of IGI Global

Managing Director: Lindsay Johnston
Managing Editor: Austin DeMarco
Director of Intellectual Property & Contracts: Jan Travers
Acquisitions Editor: Kayla Wolfe
Production Editor: Christina Henning
Development Editor: Caitlyn Martin
Typesetter: Kaitlyn Kulp
Cover Design: Jason Mull

Published in the United States of America by
Information Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue
Hershey PA, USA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com

Library of Congress Cataloging-in-Publication Data

Handbook of research on maximizing cognitive learning through knowledge visualization / Anna Ursyn, editor.
pages cm
Includes bibliographical references and index.
ISBN 978-1-4666-8142-2 (hardcover) -- ISBN 978-1-4666-8143-9 (ebook) 1. Cognitive learning. 2. Information visualization. I. Ursyn, Anna, 1955- editor of compilation, author.
LB1062.H25 2015
370.15'23--dc23
2015000388

This book is published in the IGI Global book series Advances in Knowledge Acquisition, Transfer, and Management (AKATM) (ISSN: 2326-7607; eISSN: 2326-7615)

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

Chapter 18
What Does Learning Look Like?
Data Visualization of Art Teaching and Learning

Pamela G. Taylor
Virginia Commonwealth University, USA

ABSTRACT

Drawing upon the data visualization work of Lev Manovich and Manuel Lima, in this chapter the author discusses ways for envisioning and representing the complex teaching and learning that is associated with the visual arts. Experiences and examples are shared that use new and old technologies to create and make connections among critically reflective collections of student learning artifacts such as research, journals, preliminary sketches, work in other classes, and realms of experience outside of school. Instead of relying on one final art product, the author explores embedded data mining and visualization as a viable approach to gauging student learning. Following the lead education notables Elliot Eisner (2002, 2004), John Dewey (1934), and Howard Gardner (1985), this research positions the visual arts as a common thread throughout disciplines. Such inherent and fundamental visual arts practices as portfolios, project-based instruction, and exhibition continue to expand instruction and learning in such classes as English, math, science, and history. The implications include the possibility that art education will lead the way to implementing authentic embedded assessment processes across education disciplines and grade levels.

INTRODUCTION

Most every art teacher and artist knows that a work of art is not simply one work of art. It is a combination and progression of many and varied ideas, influences, research, dreams, risks, and other life and learning experiences too numerous to mention. What if there were a way to critically capture and actually represent this process of learning and making art? How would it work and what would it look like? These questions guide and challenge this evolving research that actually began in 1999.

Drawing upon experiences from a 2-year computer hypertext-based high school art study[1] (Taylor, 1999) and a 3-year beta software development study of a virtual 3-d linking environment[2] (Taylor, 2014), this research is challenged and

DOI: 10.4018/978-1-4666-8142-2.ch018

extended through data visualization theory and practice. Specifically, this chapter will focus on data visualization principles (Lima, 2011; Manovich, 2012) and design thinking methods/categories (Berger, 2009) as possible approaches for mining and representing new and old technological data associated with teaching and learning in the visual arts. Additionally, critical and valuable social aspects of data visualization theory will be shared to represent as well as problematize sample visual representations of learning.

UNDERSTANDING DATA VISUALIZATION THROUGH AN ARTIST'S EYE

Much like the typical pie charts and bar graphs seen in math class and political analyses, data visualization functions as a way to visually represent data sets. Supposedly, such visualizations provide a clearer way to see and understand data analyses than through a narrative explanation alone. The idea of representing data in illustrative ways actually dates back to Prehistoric art with cave paintings, as well as to the carvings, scrolls, story vases and petroglyphs of ancient Egyptians, Greeks, Mayan, and Native Americans. Human beings have a strong need to see and understand data visually. Be it to provide directions, explanations, plans, strategies, or proof of an argument, more often than not a pen, pencil, computer stylus or touch pad is used to further an explanation. In the case of such artists as Leonardo da Vinci, the data visualized and indeed discovered stands the test of time. Cases in point may include the *Vitruvian Man*, images of flying machines, and the *Mona Lisa's* androgyny (Boucher, 2003).

A leading voice on information visualization, Manuel Lima is a Senior UX Design Leader at Microsoft Bing and founder of VisualComplexity.com – a visual exploration on mapping complex networks. His 2011 book entitled *Visual Complexity: Mapping Patterns of Information* is a compilation and critical representation of the processes, ideas and concepts of making data comprehensibly, logically, and beautifully visual. Lima's interests in this line of research began with his MFA thesis at Parsons School of Design in 2005. His *Blogviz* project mapped the structure of popular blog links. Looking at the idea of a meme (a culture or behavior passed from one to another), Lima began by charting the citation frequency of URLs on various blogs. Rather than represent this information as mere points on a map, Lima wanted to understand and visualize the flow/influence/connection that such frequency suggested. He studied the structure of blogs and the WWW realizing that the network of blogs is of a similar structure to most natural and artificial systems that are represented through diagrams made of nodes and lines that connect and highlight relationships between the nodes. As Lima (2011) explained, "networks are an inherent fabric of life and a growing object of study in various scientific domains. . . .This genuine curiosity quickly turned into a long-lasting obsession over the visual representation of networks, or more appropriately, network visualization" (p. 15).

Lev Manovich, professor of computer science at the City University of New York, teaches and does extensive research on new media theory. Of late, his work has focused on data visualization and specifically searchability and findability. Manovich (2012) extends the work of Mark Wattenberg who visualized such culturally significant data as a history of net art (Miranda, 2013), Wikipedia (Viégas & Wattenberg, 2010) and most watched *YouTube* videos (Matheson, 2013). With the support of grants from the Digging into Data 2011 Competition, Manovich (2013) and his team used open source image processing software designed for use in medical research and other scientific fields to design a set of tools for media visualization of large sets of images. Projects include pages of *Science and Popular Science* magazines published 1872-1922, video game-playing recordings, all paintings by van Gogh,

and one million Manga pages. Data were gathered by measuring properties and visual artifacts such as plotting curves that show patterns of change and mapping spatial distances according to such categories as genres, styles, mediums, countries, and movements. This data can visually organized through similarities, differences, influence, location, artist, etc. Especially significant to this chapter is Manovich's (2008) challenge and value of new research directions that visualize data in the social sciences and humanities to understand "complex social processes like learning, political and organizational change, and the diffusion of knowledge" (p. 13).

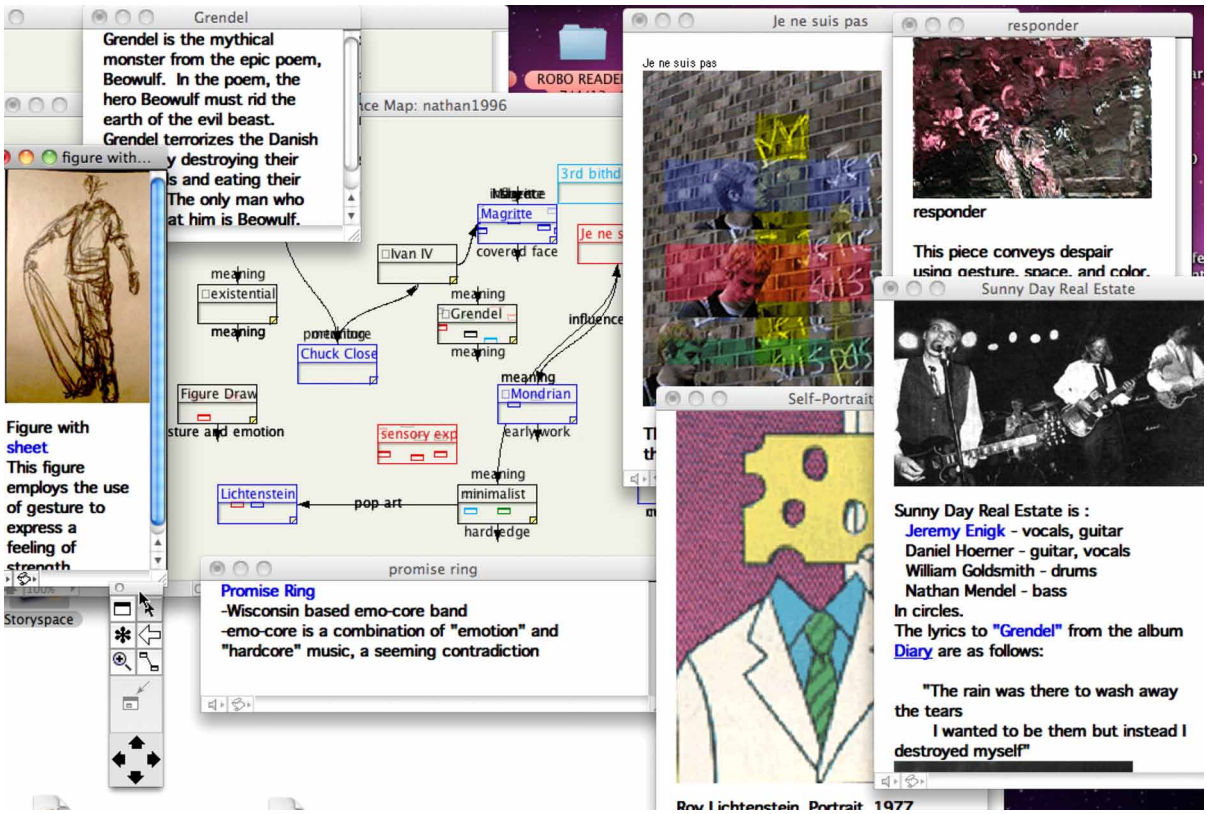
Art educator Robert Sweeny (2013) looked to data visualization as art educational research practice. Through the lens of complexity theory, Sweeny's research began with the use of network structures as interpretive tools and continued through the question "What does the relationship between works of visual art and visual culture look like?" (p. 217). His idea involved the use of complex visual networks to explore how "works of art make reference to and link together varied elements drawn from cultural, social, economic, religious, and artistic experiences" (p. 222). Sweeny shared his own visual maps based upon visual relation, text-based connections, and between works of art and visual culture. These maps consisted of thumbnail images of works of art and visual culture varied in size (according to level of connection) and arranged in a circular pattern. Zoomed screen shots depicted dots and lines superimposed on the images to reveal connections according to medium, text, subject, geographical location, economic, culture, politics, and historical references.

UNDERPINNINGS AND GROUNDWORK

A precursor of this research involving the quest for visualizing learning could be the 1999 hypertext-based art education study in which high school art students collected and represented their learning in interactive computer webs. Virtual boxes were filled with images of their art work, research, notes, comments, video, ideas from other classes, music, and other information linked to their ideas and learning. Connections were depicted with lines, arrows, and explanatory notes among boxes and specific areas like parts of images, phrases and words and attached explanations of their linking choices. Lines and arrows depicted the links creating a visual tangled web of learning. Indeed, it could be said that these interactive computer webs were visualizations of art learning to a degree (See Figure 1). The initial research confirmed that the students who based and connected their study in these interactive computer webs critically connected what they were learning in class to other disciplines and realms of experience in and outside of school. As a result, they were compelled to learn and know beyond the curriculum content and guidelines. They were also able to analyze knowledge and new information through more connective, comparative, and critically thoughtful ways than they had before the experience (Taylor, 2000).

This investigation continued for a number of years through varied class work and collaborations concerning art criticism, curriculum, artmaking, and research development (Carpenter & Taylor 2003, 2006, 2009). Most recent work to visualize learning data through an immersive engagement with the hypertext involved the beta development of an electronic learning and assessment tool for interdisciplinary connections (eLASTIC). eLASTIC was originally designed to look much like a computer game (Taylor, 2014). The current virtual artist studio, laboratory, or gallery spaces are filled with objects used to house images, text, sounds, or video clips that can be linked among other information in the environment. Basically, instead of pasting an image in a simple virtual box, in eLASTIC students import images into frames on the wall; movies are housed in video monitors;

Figure 1. An example from the 1999 hypertext-based high school web of art learning. High school art students collected and represented their studies by filling virtual boxes with images of their art work, research, notes, comments, video, other classes, music, and information linked to their ideas and learning. Connections among boxes and specific areas like parts of images, phrases and words were depicted with lines, and arrows. (© 2014, P. Taylor. Used with permission).



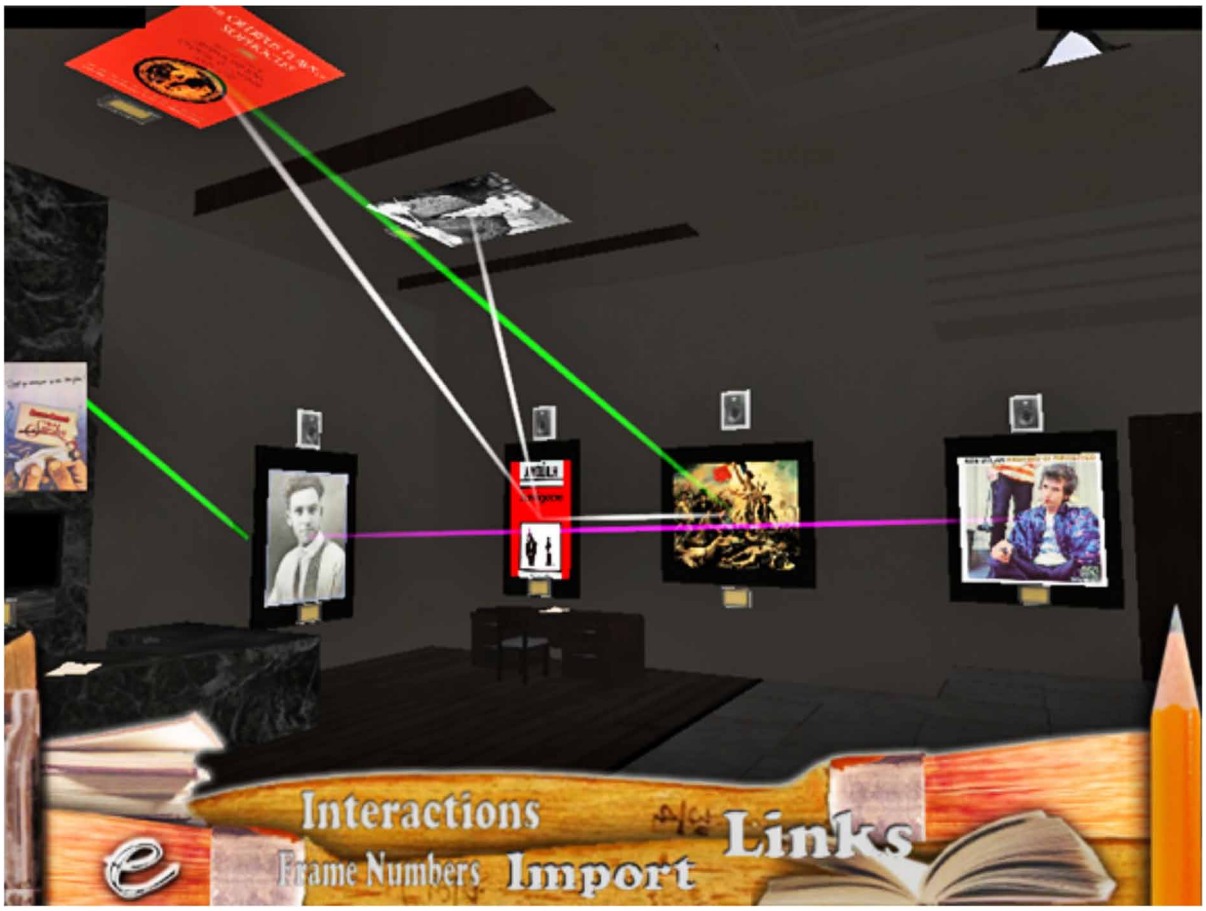
sounds are stored and played through speakers; and text is placed in various notes. Selected portions of the information placed in these objects can be linked and the links are depicted as lasers (color-coded according to student specified paths such as technique, idea, and/or context). There is an overhead view that looks much like a map, an explorer view that mimics a diagram, and 3-dimensional room views (See Figures 2 and 3).

Granted, possible visualizations of art learning in eLASTIC may include the overviews, screen shots and interactive searches along with the simple point-and-click explorations of the student hypertext constructions. But, what part did the visual components of the hypertext and eLASTIC environments play in the students' learning? The remainder of this chapter explores the ways that theory and practice of such data visualization notables as Lima (2011) and Manovich (2012) could inform this and the larger research question: Indeed, what does learning look like?

NETWORK VISUALIZATION AND DESIGN THINKING

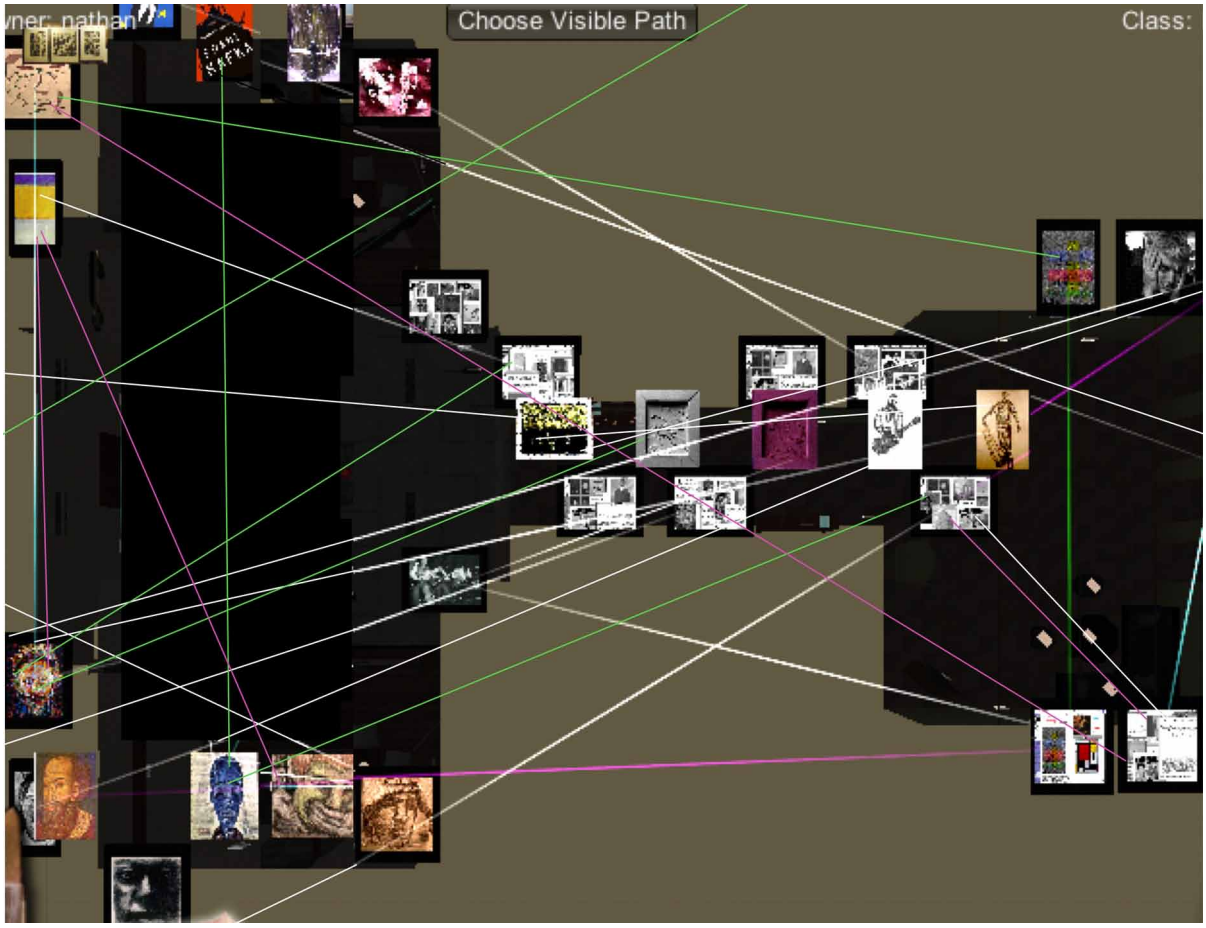
Lima's (2011) research draws from the graphical methods classification work done by Williard Brinton in 1914 and more contemporary notables such as Ben Fry (2008), Dan Sperber and Deirdre

Figure 2. In the 2012 beta version of eLASTIC, connections are visible in the room view as laser beams when the lights are switched off. (© 2014, P. Taylor. Used with permission).



Wilson (1996), Jacques Bertin (1967/2010), and Bruce Mao (2004). Approaching and creating network visualizations, according to Lima (2011) involves roughly eight principles: 1) Start with a question; 2) Look for relevance; 3) Enable multivariance; 4) Embrace time; 5) Enrich your vocabulary; 6) Expose grouping; 7) Maximize scaling; and 8) Manage intricacy (pp. 82-92). In a similar vein, Warren Berger (2009) outlined ten methods/categories of design thinking in his book *CAD Monkeys, Dinosaur Babies and T-Shaped People: Inside the World of Design Thinking and How it can Spark Creativity and Innovation*: 1) Ask stupid questions; 2) Jump fences; 3) Make hope visible; 4) Go deep; 5) Work the metaphor; 6) Design what you do; 7) Face consequences; 8) Embrace constraints; 9) Design for emergence; and 10) Begin anywhere (pp. 21-267). To further the idea of representing learning visually, the remainder of this chapter will correlate Lima's data visualization principles and Berger's design thinking methods/categories. Examples from the 1999 hypertext and 2012 eLASTIC research studies will be offered as illustrative cases, as well as provocative questions to these theories. Research methodological approaches for mining and representing data associated with teaching and learning in the visual arts will be discussed and imagined further through descriptions and visual representations.

Figure 3. The eLASTIC overhead view mimics a map or floor plan of the virtual environment. Lines are color-coded according to the student's chosen trail or path such as technique, influence, artist, and or timeline. (© 2014, P. Taylor. Used with permission).



Questioning Visualizations

Lima's (2011) first principle "Start with a question" (p. 81) and Berger's (2009) initial consideration of "Ask stupid questions" (p. 21) obviously point to the importance of the purpose and meaning of visualization and design. Contrary to these principles, Manovich (2012) challenged data visualizers to work "against search" and "look without knowing what you want to find" (p. 2). Lamenting hierarchical classification systems, Manovich challenged researchers to move beyond postulating "what was there or what are the important types of information worth seeking out." In other words, "searching assumes that you want to find a needle in a haystack. . . .It does not allow you to see the shape of the haystack. . . .it does not reveal what else there is worth seeking" (p. 3).

Teaching and learning are highly complex, individual, and often subjective. Indeed, the visual representation of teaching and learning would necessitate many forms. Add the intricacies associated with visual art learning, thinking, making, and teaching and the possibilities become formidable, yet inspiringly exciting. Works of art, of course could be said to be the ultimate data visualization. Further, as Lev Manovich (2011) wrote:

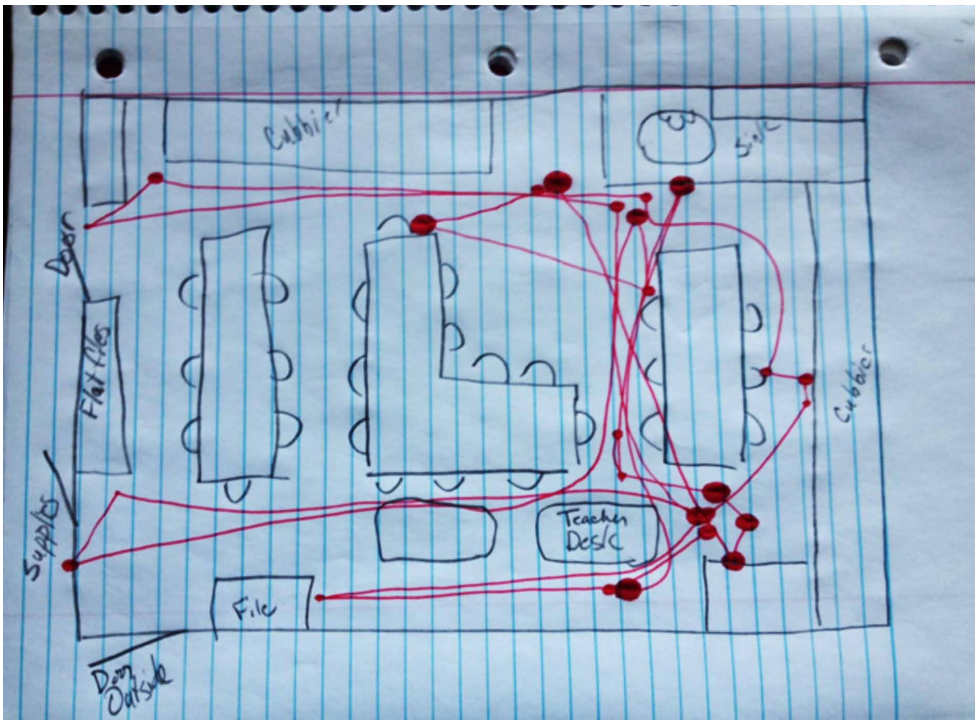
Visualizations can also function as art in a different sense: an activity aimed at making statements and asking questions about the world by selecting parts of it and representing these parts in particular ways. Some of the most well-known artistic visualizations projects do exactly that: they make strong assertions about our world not only through the choice of visualization techniques, but also though the choice of data sets (p. 13).

The primary question being addressed—in this case, what does learning look like?, often determines the way or approach to the visualization creation. But, visualizing teaching and learning is a highly charged and controversial endeavor. Other important issues to consider include: What if there were ways to represent as well as problematize visual representations of learning? In other words, can teaching and learning be visualized critically to both represent and challenge?

A visualization of the paths a teacher takes throughout her or his classroom may aid in the understanding of classroom management issues, room design restraints to learning, as well as personal bias/value issues that need to be addressed. When observing student teachers, Dr. B. Stephen Carpenter uses a technique in which he draws a quick floor plan of a classroom and then uses a marker to draw the student teachers' walking paths. When the student teacher stops, Carpenter hold his marker in one place as it literally bleeds into the paper. This visualization demonstrates the areas where (and with whom) the student teachers spend most of their time, as well as the places (or students) they avoid (personal communication, April 21, 2001) (See Figure 4).

Some students involved in the eLASTIC research created maps of some of their paths of thinking by connecting color-coded links from sketches and paintings related to specific tech-

Figure 4. Visualizations, such as this map/classroom floor plan provide an annotated reflection of student teachers' instructional strategies regarding position and space. (© 2014, P. Taylor. Used with permission).



niques of artists and writers. Prior to working with the computer hypertext software, students created paper-based concept map visualizations on which they made connections among specific keywords, ideas, research, and sketches. Indeed, some visual art students' journal/sketchbooks could be considered three-dimensional visualizations of their learning as they are often very inclusive of a wide variety of inspirational artifacts. Journal/sketchbooks are typically connectively organized with tabs or other markers so that young artists can easily find and share their paths of discovery. In the original hypertext study, students often presented their pre-computer work in performative ways. For example, they physically shared and connected pages of a journal on a table, books on a shelf, posters on a bulletin board, notes in a notebook, and art on an easel by holding hands, using wire, drawing lines on the floor or simply moving and swaying between and among the linked objects. They were performing their own learning data.

Time, Hope, and Consequences of Visualizing Teaching and Learning

In his chapter "Make Hope Visible" (p. 70) Berger supported the idea that there is an integral responsibility of, as well as sustainable stewardship associated with design and innovation. Lima (2011) explained his principle of "embracing time" as a means of measuring and mapping to comprehensively understand the dynamics of social groups. Such an approach could be linked to Berger's (2009) ideas of "facing consequences" (p. 183) or coming to terms with the responsibility of design and "embracing constraints" (p. 211) or repurposing problems. Such issues may urge the questions: Could visualizing data associated with teaching and learning do harm to students and/or teachers? Would it tell things that no one wants to know and what does that mean? If the visualization is primarily technology driven, what measures or considerations should be taken to insure equal access?

For example, the original hypertext research actually was dependent upon a specific computer program that was purchased and only used by participants for a part of the research project. Consequently, the use and approach ended when the project, class, and experience was over. Likewise, the second major part of the research involved the development of specific software that was again abandoned by the participants when the project ended. Many participants felt that using the software was actually disruptive to their learning because it was yet another separate program or application from what they already used. They wanted to be able to gather or mine data from the technology that they were comfortable with and wanted to use on their own such as social media. Some students in the two studies had their own personal computers and some didn't. And other students were able to obtain the software so that they could work at home. However, not all students had computers at home.

As exciting and interesting as many of the student eLASTIC environments were, only a few of the researchers were actually able to analyze the intricacies of the links and associations. Not all of the researchers were familiar with art terms and techniques. Some of the researchers did not understand the nuances of the program itself. And, some of the researchers had difficulty understanding the connections that the students made with such contemporary youth culture as popular music and gaming. These issues then beg the questions: Is it possible for everyone to understand the implications or representations of data visualizations? If the visualizations are representative of such highly charged data as student learning, what happens if they are misinterpreted?

Relevance, Fences, and Multivariance Associated with Data Visualization

Lima's (2011) principle "look for relevancy" (p. 81) and Berger's (2009) category "jumping fences"

(p. 45) point to the significance and connection among the representation, the initial question, subsequent issues, and audiences. In other words, who or what else does the design inform, represent, suggest? Does it matter? Is it worth doing or seeing? Similarly, Lima's principle "enable multivariate analysis" suggests and indeed pointedly calls for the value of more than one outcome variable. "The ties among elements in a network are immensely rich and detailed, and the inclusion of additional information can be fundamental in the unveiling of many of these nuances" (Lima, 2011, p. 81).

Interactive visualizations that offer multiple levels of information may serve to represent the numerous layers of teaching and learning. The point then is to work out a way to capture the various patterns and meanings that we notice when we directly watch, view, read, and interpret actual teaching, learning, and artifacts, "as opposed to metadata about them" (Manovich 2012, p. 2).

According to an interesting word cloud published in *Harvard Magazine*, the most essential ingredients of good teaching and learning captured at a Harvard Initiative for Learning and Teaching conference included: engagement, listening, active, connections, curiosity, understanding, knowledge, and collaboration. These are represented as most essential by their large, bold, and bright font, size and color on the word cloud (Advancing the Science and Art of Teaching, 2013). The word cloud listed many more ingredients such as creativity, criticality, focus, interest, ideas, passion, inspire, etc. But, what if visualizations were designed to capture those first 8 ingredients during an actual classroom observation? What would it look like? Could it be like a popup video that was programmed to record and annotate at the same time? Or perhaps an observer would have that ability on a tablet computer in a similar way as Carpenter's student teacher observation process discussed earlier in this chapter. The layers, time, and pathways of teaching and learning, are but a few of the many influential aspects that should also come into play when considering the visualization process. How and through what ways does one come to teach and know? Can someone track their personal journey of knowing in the visual arts in a way that others could understand? What would that look like?

Language, Vocabulary, and Design of Visualizations

Both Lima (2011) and Sweeny (2013) explain that much of the vocabulary and design of data and network visualization is associated with two primary elements— nodes and links. Varied representations of those nodes and links include such visual properties as shape, size, texture, intensity, line variation, etc. Lima also suggested using expressive edges and layering, but quoted Ben Fry's (2008) warning that, "One of the caveats behind the implementation of diverse graphical attributes it to beware of creating a visual language that might not be immediately recognized by everyone" (p. 4). Berger suggested the idea of designing what you do. In other words, designing behavior or for the purposes of this research, using a design approach to not only represent teaching and learning in a visual way, but design varied relevant and selective methods for gathering the data. As stated at the beginning of this chapter, a painting is not just one painting. Put another way, one finished work of art does not represent or make apparent all the valued learning in the art class. There are multiple indicators/artifacts of learning that are equally as valuable. So, how can those indicators be designed so that data is readily available for visualization?

Specific data was made available in the original hypertext study (Taylor, 1999) and the eLASTIC research study (Taylor, 2014) through the use of templates. For example, required information included names of the artists they studied, personal and political influences, historical facts, media and aesthetic theories. Students also needed to add any of their own personal information that

affected their interpretation of the artist and that influenced the art that they ultimately created. Other requirements included links related to media, technique, style and idea. Created primarily as a guide and starting point for the students, the template inspired the students to move beyond the requirements to alter the spaces, questions, ideas, objects, and links according to their own interests and trails of thoughts. Looking back now, the subject, objectives and standards of the course units were an intricate component of the template. Therefore, they could easily be related to data visualization categories/indicators. Interesting too, was the fact that the students seemed to intuitively use standard-related and data mineable labels for their links, paths, and boxes (nodes) on their own. These labels could serve as data points or sets, as well.

Groups, Metaphors, and Visualizations

Lima (2011, 2014) drew attention to artistic and graphical design elements associated with grouping of similarity, spatial proximity, and direction. Items of similar size, color, and shape typically depict likeness and/or connection as do objects that are close to each other or moving in the same direction at similar speeds (p. 91). Methods/trends for representing the connections, associations and/or causes and effects of teaching and learning may include arc diagrams, flow charts, organic rhizomes, mapping, and timelines (See Figure 5).

Metaphors may be used to represent an idea, connection, and/or objects in a visualization. Even more relevant is Berger's (2009) suggestion that the metaphorical experience should be one of complete immersion. Design should not get in the way of, but should encourage engagement within the experience (p. 145). Much like Starbucks encourages patrons to stay for unlimited hours, how can the environment, activities and other contributory indicators of learning be designed to captivate learning data while at the same time offer grouping and metaphorical visualization possibilities?

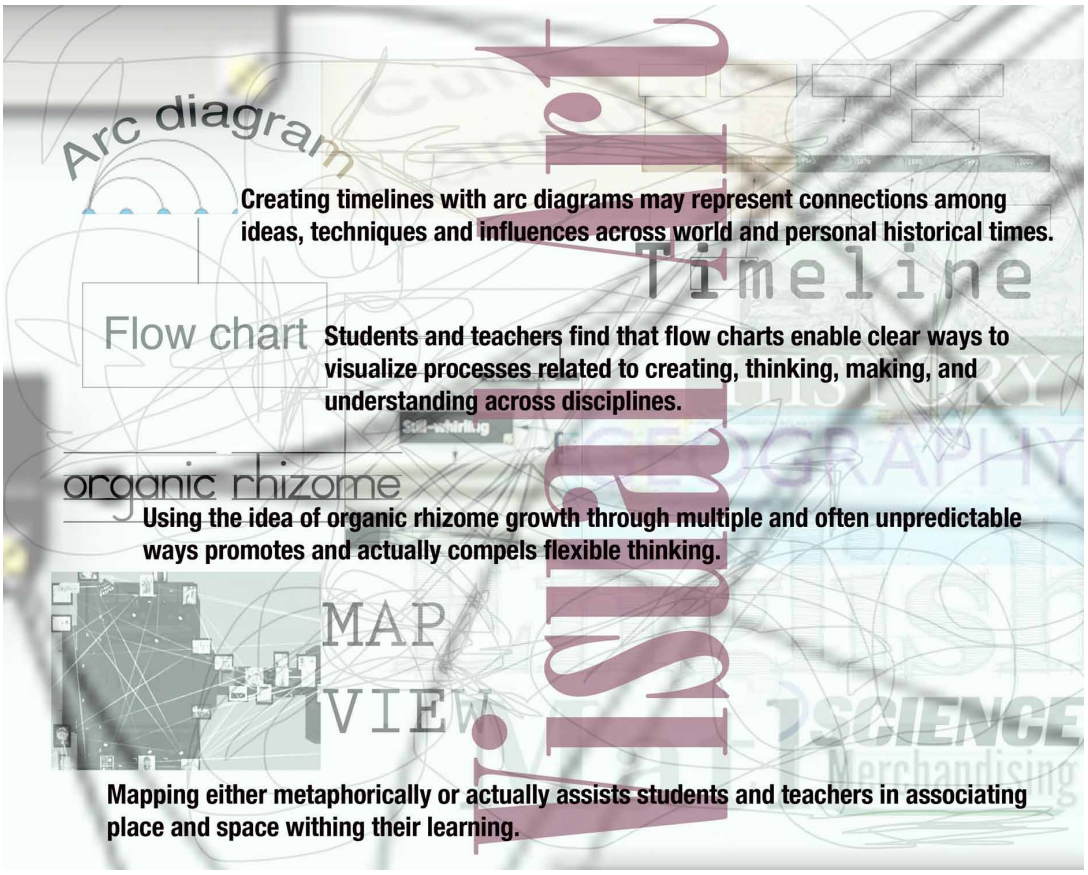
One way is through visual metaphoric space as in the virtual gallery space design of the eLASTIC interface. Interestingly just as Lima (2011) and Berger (2009) suggest, the students preferred more structured design elements such as the color-coded boxes and templates of the original hypertext software. In retrospect, the students preferred starting with the template and then altering the structure of the hypertext as they began seeing and adding connections and information of their own. Students in the eLASTIC study couldn't alter the virtual environment. They could only change the information that they placed in the objects. They could not change or bring in new objects to the environment. This seems to indicate that active student engagement in visualizing learning will probably result in more meaningful data, which in turn will result in a more accurate and meaningful visual representation.

Views and Depth of Data

Several factors greatly affect view and interpretation of works of art and data analysis including vantage point, zooming, panning, and cropping. Lima (2011) suggested there are three fundamental views macro (birds eye), relationship (visible inks) and micro (individual nodes). All three views are not always necessary in a single data visualization, but "the more questions it is able to answer, the more successful it will be" (Lima, 2011, p. 92).

Multiple views of both the hypertext and the eLASTIC software offer readers and creators varied ways to approach the information and structure of connections within the student art web environments. An overhead or map view looks much like a concept map with titled lines and arrows meandering among boxes, objects,

Figure 5. This overview features five data visualization methods along with their possible interdisciplinary applications in teaching and learning. (© 2014, P. Taylor. Used with permission).

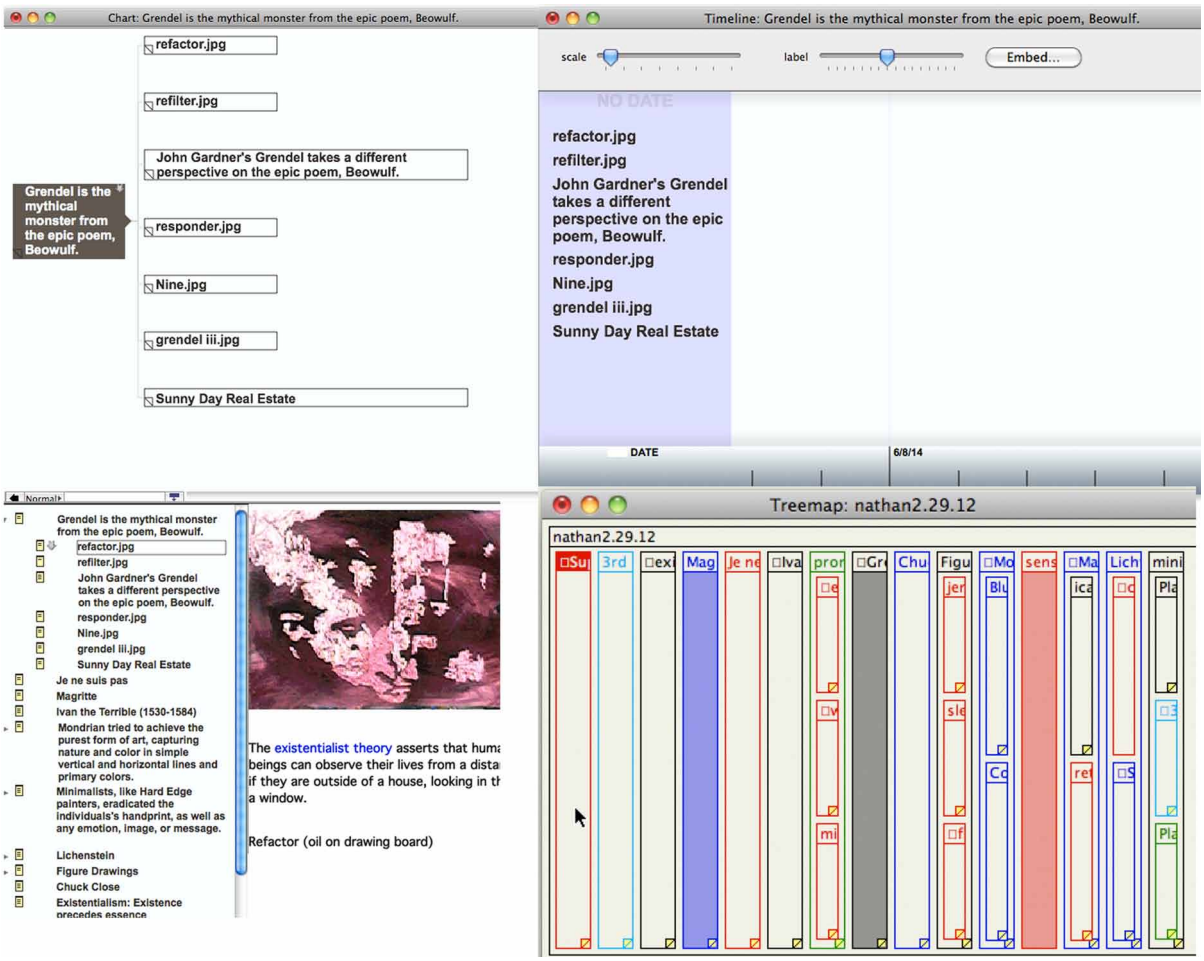


and spaces. Chart, outline, and treemap views provide a more hierarchical inspection of the file/portfolio/web/visualization. A map or radial view mimics a mind or web map of all objects in the space. (See Figures 6 and 7).

These multiple views reveal connections and trails of thoughts that are very interesting and could inform and exemplify teaching and learning. But, going deep and "getting down into the muck and beauty" (Berger 2009, p. 99) of design, data, and learning suggest the need for scrutiny and deep investigation into the purposes or core business of what is and/or should be going on in the classroom. What do teachers and students really need to be successful? What does success look like and how can it be visualized?

A visualization of a students' thinking trails as diagrammatic paths in a virtual/metaphoric environment may represent what is going on in the art classroom. An even more detailed inspection is possible with the side-by-side comparisons of connected spaces in the explorer views (See Figure 7). But, much closer scrutiny is needed to authentically understand such nuance as; In what order did the student make these connections?; How long did it take for the student to come to this conclusion?; Did a particular author or artist influence the student to look at his or her work in a particular way before or after they made the connection to another artist or author's technique or style? Something as simple as adding date and time stamps attributes to each data entry as well

Figure 6. Multiple visual representations from the original hypertext study include the: chart (top left), timeline (top right), explorer (bottom left), and treemap views (bottom right). (© 2014, P. Taylor. Used with permission).

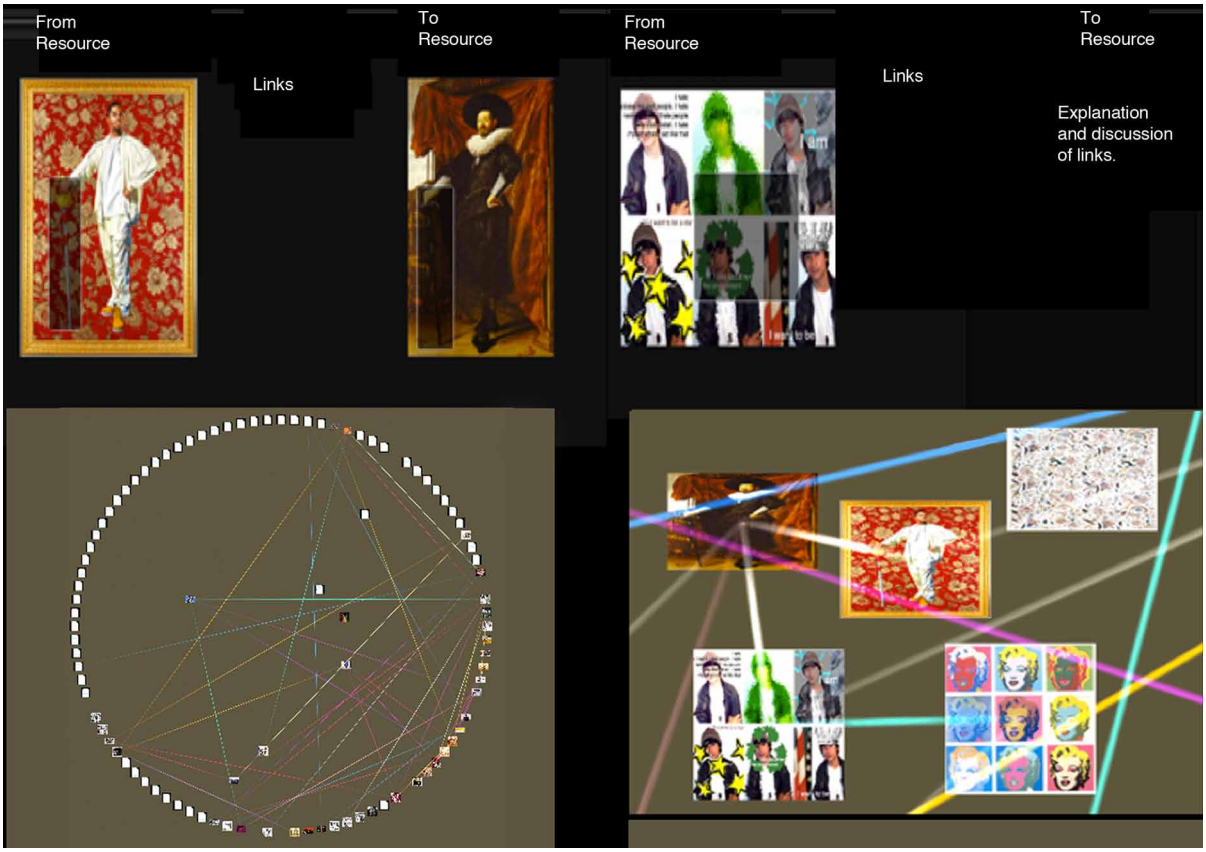


as a software-controlled directional feature may assist in providing more accurate and meaningful data for closer scrutiny.

Details, Emergence, and Patterns of Learning Data

There is a great deal of detail and intricacy to gathering, analyzing, and visualizing data. Data sets are typically highly complicated. Lima (2011) recommended that such complexity of data be managed through an overview, zoom and filter to enable users to easily locate specific areas or patterns of interest (p. 92). Berger (2009) looked at the intricate details or patterns of everyday life as designs for emergence and transformation. Key lessons of such an approach include: 1) design in a way that is self-sustaining and conducive to growth; 2) develop community relationship patterns; 3) keep learning; and 4) keep creating and inventing (p. 247). Important to Berger too, is the recognition that "small actions are more important

Figure 7. Multiple visual representations from the 2012 eLASTIC study include Explorer view (Top left and right) and Radial view (bottom left) shows all linked objects along with a zoom feature (bottom right). (© 2014, P. Taylor. Used with permission).



than big plans" (p. 267). The following is a comment concerning volunteerism and social justice by designer Bruce Mau in Berger's (2009) book. I use it here to support the idea that visualizing teaching and learning data can like teaching and learning, be a form of social action.

Something is happening out there. People are seeing the world around them with greater resolution, because there is more information available to them. For the first time, they are seeing patterns that have been invisible to the larger public in the past. We are moving toward global clarity—to people finally being able to say, "Oh, I get it. Now I see what's going on in the world" (p. 291).

IDEAS AND STRATEGIES FOR VISUALIZING PATTERNS OF VISUAL ART LEARNING

The process of making art is filled with rich and meaningful questioning, researching, risking, failing, exploring, comparing—in essence the very principles of data visualization and design thinking that guided this research. Art curriculum design is typically begun with a question whether through backward design, standards of learning, proficiency levels, works of art or ideas. Vigilant teachers ask, is this worth knowing or doing and why? What will students know and be able to do following a particular learning experience? What

relevance is there in a certain lesson that may serve to motivate, inspire, encourage, and make a difference? Teachers work toward multiple methods and indicators of learning. They recognize and embrace the dynamics of cultural, gender, age, and social groups. Each class consists of vocabulary expansion, grouping, comparing, and approaching art at various levels and scales. Boundaries are crossed as students are deeply engaged in work that makes a difference in their world. Learning about and making art involves design and metaphor. It requires an understanding of consequences and constraints of media and ground. And meaningful art and education requires that artists and teachers think deeply about how their work may provoke action, understanding, awareness and/or simple appreciation through our art and curriculum.

Indeed, if the principles of data visualization and design thinking are so intricately involved in art education, then one might assume that they may in some way determine the patterns associated with a visualized network of art teaching and learning. What would an art education network look like? Conversely, Lima (2011) warned, "Networks are very difficult to visualize and we do not need to make them more complex in the process of trying" (p. 95). The ultimate goal is communicating relevant information. So, what is the relevant information in art education? University of North Carolina data visualization professor Robert Kosara (2007) wrote that often: "The goal of artistic visualization is to communicate a concern rather than to show data" (p. 4). The major concern of this book is maximizing learning through knowledge visualization. Another leading and high stakes issue in education deals with assessment and the ability to reveal concretely the degree of learning that is going on in visual arts classrooms. There are other important concerns as well, that although they extend beyond the purview of this chapter, their social significance suggests the need for more than a mere mention. The value of teaching and learning in the visual arts; access to quality art education for all students; funding; student/teacher ratio; classroom space; the need for cultural and LGBT understanding in both teaching and subject matter; social justice in practice and curriculum; and value of and training for teachers to work with students with special needs in the art classroom, to name a few. Although these often highly charged issues may be viewed as too political and controversial for the public arena of school, they are very much a part of our education landscape and ultimately an integral part of the data visualization. According to Dörk, Feng, Collins, and Carpendale (2013) "As visualizations continue to grow in importance, there is a need to think more systematically about how values and intentions shape visualization practice" (p. 2). As such, Dörk, Feng, Collins, and Carpendale suggest examining hidden intentions and values, giving full disclosure of data sources, compelling multiple interpretations/possibilities, and enabling questioning when approaching data visualization design.

Similarly, it is important to understand how visualizations are interpreted and misinterpreted through social lenses. Cultural coding, visual metaphor, and symbolic representation as well as personal and idiosyncratic taste and preference make visual interpretation highly subjective. Manovich's (2013) idea that visualizations, like art can be created in ways that make strong assertions about the world add another complex layer to the idea of authentically envisioning schooling. There is no getting around the fact that the choices made in the visualization of data in some way affect the accuracy of that representation.

That said, the following are presented as initial strategies to be considered when formulating data visualizations of student art learning.

1. Design the language of teaching and learning (curriculum) with indicators (data) of learning in mind.
2. Work toward producing multiple and fluid purposes/functions for visualizations that can represent as well as challenge.

3. Remain vigilant in the quest to visualize needs as well as successes in teaching and learning.
4. Work toward inclusive and relevant approaches toward data representation acknowledging that there may be more outcome variables than expected.
5. Consider interactive visualizations for chronicling multilayered and multidisciplinary learning.
6. Take advantage of similarity, spatial, color, shape, and directional grouping to assist in visual identification of likeness.
7. Clearly explain the visual metaphors used to represent ideas, connections, and/or objects.
8. Provide multiple views and magnification features to allow for understanding of greater detail and alternative perspectives.
9. Highlight patterns in recognizable ways while at the same time honestly conceding other possible questions for interpretation.
10. Recognize that visualizations are not necessarily universal languages and offer multiple visual interpretive strategy keys or legends from which to draw.

HOPEFUL RESEARCH VISIONS OF LEARNING DATA VISUALIZATION

The future uses, effects, and hopes of data visualization in art and education may inform the actions of educators as well as portray what is going on, the needs, what the students are doing, and what the implications are of goals and practice. In other words, "a well-designed visualization should have the unique power to also help shape our identity as well as our experience" (Lima, 2011, p. 251).

Initial work with graduate students who created data visualizations based on their literature review explorations revealed some interestingly varied structures. One student transformed his pursuit of education theory and practice relating to students with autism into a jigsaw puzzle game box. Another student created multiple clear acetate sheets that told separate stories by themselves and built numerous stories as they were layered together. Two other visualizations used the hypertext software along with Photoshop. Data from their literature review is housed within the pictured spaces and they have distorted, transformed, colorized, layered, and extruded to create effects that related to their chosen topics of community arts and online learning (See Figures 8 and 9). They explain their process:

The data visualization unintentionally captured how what I was learning and how I was learning was so closely linked to my personal experience. What began as a casual, yet earnest foray into community-based art education became a startling realization about the importance of examining the day-to-day, "the ritualized inconsequential", the familiar and thereby making it strange. The time of my research coincided with my first semester of graduate school, a time of personal growth and great insight into my own learning process. To represent this, when designing the piece, I used images of the Blue Ridge Mountains behind my parents' home, layering them to create a new different perspective on the familiar setting from my childhood (E. Ogier, personal communication, August 19, 2014).

The data visualization became a visual metaphor of the links I was making while learning more about education theorist Jerome Bruner. It started as a Tinderbox layout with playing blocks in the background. The further I went into the topic the more patterns and themes I found. I thought more about what toys might provide a similar visual experience and remembered my first time looking through a kaleidoscope. I felt this fit well as a kaleidoscope allows you to see a collection of objects in an also infinite number of patterns and colors. In the case of this visual the blocks represented various literature and researchers I connected to the topic being viewed inside the

Figure 8. Graduate student used multiple layers along with screen shots of her hypertext file to add personal experiences, value of nature and community in her literature review data visualization. A magnified area of the visualization is featured in the upper right corner of the figure. (© 2014, P. Taylor. Used with permission).

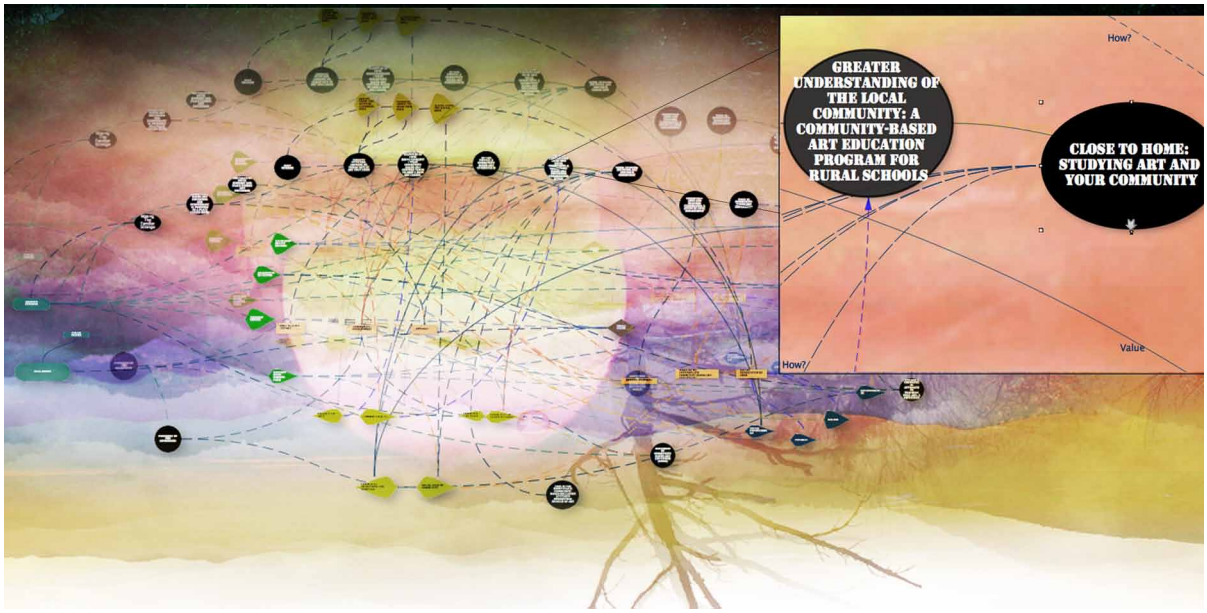
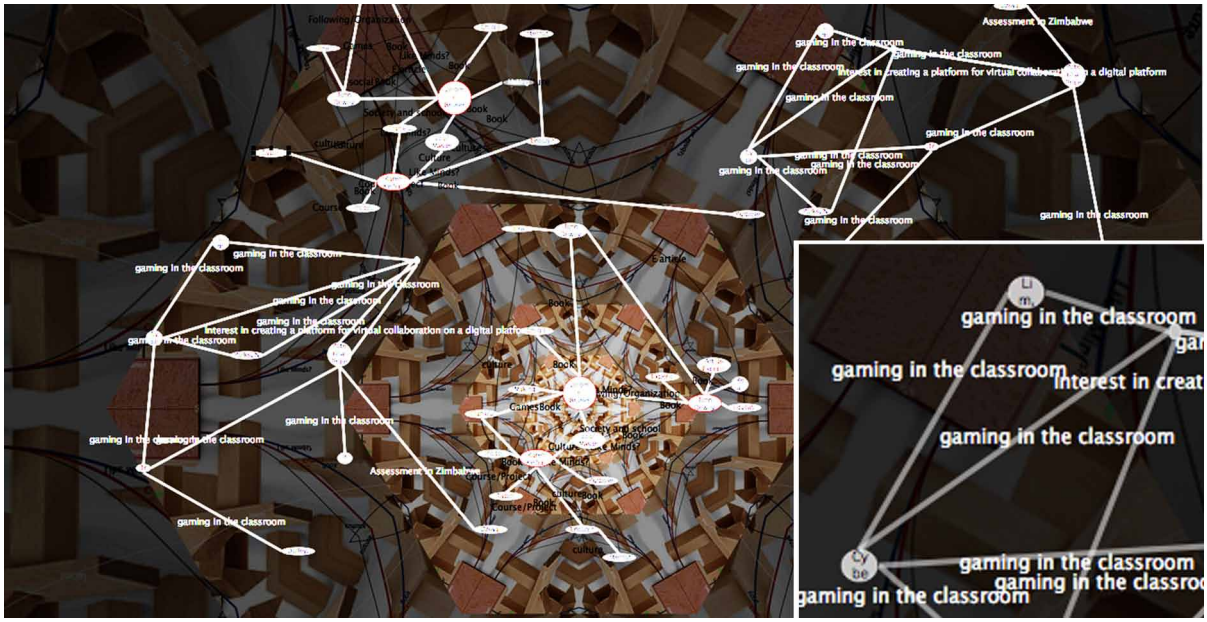


Figure 9. In this visualization, the graduate student added a kaleidoscope pattern to reflect the multifaceted theories of education he was experiencing for the first time. A magnified area of the visualization is featured in the lower right corner of the figure. (© 2014, P. Taylor. Used with permission).



kaleidoscope. This matched my experience up to that point as I struggled with the frustration of not being able to present every pattern I found through out the process. The data visualization is only one representation among an almost infinite amount of possible outcomes (M. Kahari, personal communication, August 21, 2014).

These first attempts at visualizing learning consisted of maps or paths of learning using metaphors of a web, map, pathways, and traces. The students extended those maps to include more personal metaphors and designs. Future goals and considerations include: more student created data visualizations; multiple format accessibility and maneuverability; direct links to multiple applications; archiving features; data mining capabilities across platforms and programs; social networking and feedback capabilities; visually multidisciplinary; and smart phone and tablet applications and push notifications. The implications this research suggests that ongoing and deliberate data collection and connection serve to maximize cognitive and creative learning in the visual arts.

CONCLUSION

Recognizing and understanding the process of cognitive learning is crucial to teaching and schooling. In particular, awareness of the thinking and creative process in visual arts education is paramount in understanding student growth and progress. This chapter focused on the ways that data visualization and design theory and practice could inform the creation of authentic and meaningful representations of learning in the visual arts. Critically capturing and representing the learning and artmaking processes through initial hypertext and eLASTIC research was both presented and challenged. Because teaching and learning accountability continues to be an important undertaking for every class including visual art, such information gathering is extremely important. The standing of art education will be greatly bolstered by meaningful and authentic data visualizations of student art learning.

ACKNOWLEDGMENT

The research was made possible by the support of a National Priorities Research Program grant from the Qatar National Research Fund and a research grant from the National Art Education Association Foundation.

REFERENCES

Advancing the Science and Art of Teaching. (2013). *Harvard Magazine*. Retrieved June 9, 3013 from http://harvardmagazine.com/2013/05/harvard-learning-and-teaching-innovations

Berger, J. (2009). *CAD monkeys, dinosaur babies, and t-shaped people: Inside the world of design thinking and how it can spark creativity and innovation.* New York: Penguin.

Bertin, J. (2010). *Semiology of graphics: Diagrams, networks, maps.* Redlands, CA: Esri. Originally published in French in 1967

Boucher, B. (2003). Does the "Da Vinci Code" crack Da Vinci? *New York Times.* Retrieved January 22, 2014 from http://www.nytimes.com/2003/08/03/books/art-architecture-does-the-da-vinci-code-crackleonardo.html?pagewanted=all&src=pm

Carpenter, B. S., & Taylor, P. G. (2003). Racing thoughts: Altering our ways of knowing and being through computer hypertext. *Studies in Art Education, 45*(1), 40–55.

Carpenter, B. S., & Taylor, P. G. (2009). You've got to see this: Looking back on/forward from online hypermediated art criticism and collaborative digital technology. In T. Kidd & I. Chen (Eds.), *Wired for learning: An educator's guide to web 2.0* (pp. 215-232). Charlotte, NC: Information Age Publishing.

Carpenter, B. S., II, & Taylor, P. G. (2006). Making meaningful connections: Interactive computer hypertext in art education. *Computers in the Schools, 23*(1/2), 149–161. doi:10.1300/J025v23n01_13 doi:10.1300/J025v23n01_13

Dewey, J. (1934). *Art as experience.* New York: Minton, Balch & Company.

Dörk, M., Feng, P., Collins, C., & Carpendale, S. (2013). Critical infovis: Exploring the politics of visualization. In *Digital interaction at culture web*. Newcastle University. Retrieved June 7, 2014 from: http://di.ncl.ac.uk/publicweb/publications/altchi2013.pdf

Eisner, E. W. (2002). What can education learn from the arts about the practice of education? In *The encyclopedia of informal education*. Retrieved August 24, 2014 from www.infed.org/biblio/eisner_arts_and_the_practice_or_education.htm

Eisner, E. W. (2004). *The arts and creation of mind.* New Haven, CT: Yale University.

Fry, B. (2008). *Visualizing data*. Sebastopol, CA: O'Reilly Media.

Gardner, H. (1985). *Frames of mind: The theory of multiple intelligences*. Basic books.

Kosara, R. (2007). Visualization criticism – The missing link between information visualization and art. In *Proceedings of 2007 Information Visualization Conference*. Zürich, Switzerland: Academic Press. Retrieved February 13, 2014 from http://kosara.net/papers/2007/Kosara_IV_2007.pdf

Lima, M. (2011). *Visual complexity: Mapping patterns of information.* New York: Princeton Architectural Press.

Lima, M. (2014). *Manuel Lima: Interaction designer, information architect, design researcher*. Retrieved February 10, 2014 from: http://www.mslima.com/myhome.cfm

Manovich, L. (2008). *Visualizing image and video collections*. Retrieved January 29, 2014 from http://labsoftwarestudies.com/2008/09/cultural-analytics.hml

Manovich, L. (2011). Foreword. In M. Lima (Ed.), *Visual complexity: Mapping patterns of information* (pp. 11-13). New York: Princeton Architectural Press.

Manovich, L. (2012). Media visualization: Visual techniques for exploring large media collections. In K. Gates (Ed.), *Media studies futures*. Retrieved January 29, 2014 from http://manovich.net/DOCS/media_visualization.2011.pdf

Manovich, L. (2013). *How to compare one million images? Visualizing patterns in art, games, comics, cinema, web, print, and user-generated content*. Lecture at Virginia Commonwealth University.

Mao, B. (2004). *Massive change*. London: Phaidon.

Matheson, W. (2013). Map: What YouTube videos are your neighbors watching? *USA Today.* Retrieved February 19, 2014 from http://www.usatoday.com/story/popcandy/ 2013/05/10/youtube-trends-map/2151253/

Miranda, C. A. (2013). The new world of net art. *ARTnews*. Retrieved February 19, 2014 from http://www.artnews.com/2013/06/12/the-new-world-of-net-art/

Sperber, D., & Wilson, D. (1996). *Relevance: Communication and cognition.* Hoboken, NJ: Wiley Black-Blackwell.

Sweeny, R. (2013). Complex digital visual systems. *Studies in Art Education, 54*(3), 216–221.

Taylor, P. G. (1999). *Hypertext-based art education: Implications for liberatory learning in high school.* (Unpublished dissertation). The Pennsylvania State University, State College, PA.

Taylor, P. G. (2000). Madonna and hypertext: Liberatory learning in art education. *Studies in Art Education, 41*(4), 376–389. doi:10.2307/1320680 doi:10.2307/1320680

Taylor, P. G. (2014). eLASTIC: Pulling and stretching what it means to learn, know, and assess art and educational progress. *Studies in Art Education. I*, *55*(2), 128-142.

Viégas, F., & Wattenberg, M. (2010). Beautiful history: Visualizing Wikipedia. In J. Steele & N. Ilinsky (Eds.), *Beautiful visualization: Looking at data through the eyes of experts (theory in practice)* (pp. 175–192). Sebastopol, CA: O'Reilly Media.

ADDITIONAL READING

Carpenter, B. S., & Taylor, P. G. (2003). Racing thoughts: Altering our ways of knowing and being through computer hypertext. *Studies in Art Education, 45*(1), 40–55.

Carpenter, B. S., & Taylor, P. G. (2009). You've got to see this: Looking back on/forward from online hypermediated art criticism and collaborative digital technology. In T. Kidd & I. Chen (Eds.), *Wired for learning: An educator's guide to web 2.0* (215-232). Charlotte, NC: Information Age Publishing.

Carpenter, B. S., II, & Taylor, P. G. (2006). Making meaningful connections: Interactive computer hypertext in art education. *Computers in the Schools, 23*(1/2), 149–161. doi:10.1300/J025v23n01_13 doi:10.1300/J025v23n01_13

Carpenter, S. (2010). The beauty of data visualization: David McCandless on TED.com. *TEDBlog*. Retrieved September 28, 2014 from http://blog.ted.com/2010/08/23/the-beauty-of-data-visualization-david-mccandless-on-ted-com/

Lima, M. (2014). *The book of trees: Visualizing branches of knowledge.* Princeton, NJ: Princeton Architectural Press.

Manovich, L. (2009). Cultural analytics: Visualizing cultural patterns in the age of "new media." *Manovich.net.* Retrieved September 28, 2014 from http://manovich.net/index.php/projects/cultural-analytics-visualizing-cultural- patterns

Manovich, L. (2009). From reading to pattern recognition. *Manovich.net.* Retrieved September 28, 2014 from http://manovich.net/index.php/projects/article-2011

Manovich, L. (2011). Media visualization: Techniques for exploring large media collections. *Manovich.net*. Retrieved September 28, 2014 from http://manovich.net/index.php/projects/media-visualization-visual-techniques-for- exploring-large-media-collections

Manovich, L. (2014). *Data visualization as new abstraction and anti-sublime*. Retrieved September 28, 2014 from http://manovich.net/index.php/projects/data- visualisation-as-new-abstraction-and-anti-sublime

Manovich, L. (2014). Watching the world. *Manovich.net*. Retrieved September 28, 2014 from http://manovich.net/index.php/projects/watching-the-world

Manovich, L., Douglas J., & Zepel, T. (2011). *How to compare one million images.*

Manovich.net. Retrieved September 28, 2014 from http://manovich.net/index.php/projects/how-to-compare

McCandless, D. (2014). *Knowledge is beautiful: Impossible ideas, invisible patterns, hidden connections—visualized.* New York: Harper Design.

Napolitano, P. (2014). Manuel Lima: Mapping the information space. *Digicult.it.* Retrieved September 28, 2014 from http://www.digicult.it/digimag/issue- 064/manuel-lima-mapping-the-information-space/

Taylor, P. G., & Carpenter, B. S. (2002). Inventively linking: Teaching and learning with computer hypertext. *Art Education, 55*(5), 46–52. doi:10.2307/3193958 doi:10.2307/3193958

Taylor, P. G., & Carpenter, B. S. (2005). Computer hypertextual "uncovering" in art education: Teaching for understanding through a "minds-on" approach to interactive computer technology. *Journal of Educational Multimedia and Hypermedia, 14*(1), 25–45.

Taylor, P. G. & Carpenter, B. S. (2005). Digital Kids and Visual Culture: Art Education and Curriculum in an Age of Immersive Digital Technology. *Cultuur + Educatie, De beeldcultuur van kinderen, internationale kinderkunst na het modernisme, Nr*. 15. Cultuurnetwerk Nederland, Utrecht, 47-62. (Reeks Cultuur + Educatie 15.

Taylor, P. G., & Carpenter, B. S. (2007). Hypermediated art criticism. *Journal of Aesthetic Education, 41*(3), 1–24. doi:10.1353/jae.2007.0030 doi:10.1353/jae.2007.0030

Taylor, P. G. (2000). Lindsay's Story: Hypertext and liberation in high school. In M. Bernstein (Ed.), *Hvpertext Now*. Watertown, MA: Eastgate Systems. [Online], Available http://www.eastgate.com/storyspace/art/Taylor1.html

Taylor, P. G. (2004). Hyperaesthetics: Making sense of our technomediated world. *Studies in Art Education, 45*(4), 328–342.

Taylor, P. G. (2006). Critical thinking in and through interactive computer hypertext and art education. *Innovate 2*(3).

Taylor, P. G. (2007). Press pause: Critically contextualizing music video in visual culture and art education. *Studies in Art Education, 48*(3), 230–246.

Taylor, P. G. (2014). Daring to imagine a large-scale approach to visual arts assessment. *Art Education, 67*(1), 13–19.

Trost, M. (2009). Manuel Lima at TEDGlobal 2009: *Running notes from Session 5*. http://blog.ted.com/2009/07/22/manuel_lima_at/

Viégas, F., & Wattenberg, M. (2011). How to make data look sexy. *CNN Opinion*. Retrieved September 28, 2014 from http://www.cnn.com/2011/OPINION/04/19/sexy.data/index.html?_s=PM:OPINI ON

Visual loop. (2013). Talking with... Manuel Lima: The future of data visualization, the digital dark Age. *Visual loop.com*. Retrieved September 28, 2014 from http://visualoop.com/6263/talking-with-manuel-lima

KEY TERMS AND DEFINITIONS

Backward Design: A method of designing curriculum for education that formulates what students should know and be able to do before choosing instructional strategies and evaluation instruments.

Hypertext: Text, image, parts of images, etc that is displayed and linked through a computer or other electronic device to other references. A reader may click on a hyperlink and flow to the

connected reference in a hypertext. The World Wide Web is considered a large hypertext structure.

Multidisciplinary: Refers to being composed of or combing several disciplines or subjects of study.

Multivariance: Possessing the multiple possibilities or variables of actions, ideas, or outcomes.

Performative: Unlike performing, performative reflects an act of becoming. One performs an act that creates a state of affairs such as when an officiant performs a wedding, two people become married.

Problematize: To delve more critically into a situation rather than accepting for face value. To complicate in order to understand in more detail.

Universal: Of, affecting, or done by all people or things in the world or in a particular group; applicable to everyone and everything.

ENDNOTES

1 The 2-year study involved over 200 students in Art I-Art IV classes who based all of their work in computer hypertext webs using the software Storyspace. They began their work using a Macintosh SE, then a LC III, and finally a Powerbook as the study was completed in 1997. Analyses and dissertation was defended in 1999. (Taylor, 1999).

2 This research involved the development and testing of beta software for a 3-dimensional version of the earlier hypertextual study. The research was conducted in Doha, Qatar from 2009-2012. The research was made possible by the support of a National Priorities Research Program grant from the Qatar National Research Fund and a research grant from the National Art Education Association Foundation.