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An Exploratory Study on the Meaning of Visual Scaffolding in Teaching and Learning Contexts

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This study aims to conduct a literature review on visual scaffolding. Visual scaffolding, as a support for learning, employs various forms of visual objects which can be either content-independent or content-dependent and the types of which would be abstract-verbal, concrete-verbal, concrete-visual, or abstract visual. The effectiveness of visual scaffolding can be argued in the following three aspects: 1) explicit representation of information and emphasis of critical features in effective and efficient manner, 2) supplement of additional information, 3) structural understanding with decrease in cognitive load. The limitations of the study and the suggestions for future study are discussed.

Keywords : Visual scaffolding, Visualization, Scaffolding, Visual aid, Visual scaffolding strategy, Scaffolding strategy

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Introduction

Scaffolding is an often used strategy to facilitate learning, known to provide learners with appropriate supports, thereby enabling them to accomplish tasks which would be beyond their capacity if unassisted. Furthermore, scaffolding can even be deemed to be both a structure and a process in that it guides learners in specific form to provide a highly constrained situation and learners' ongoing activities are repeatedly scaffolded until independent performance is achieved (Pea, 2004).

The concept and the mechanism of scaffolding in learning stem from Vygotsky's (1962, 1978) socio-historical perspective of the development of language and concept and the zone of proximal development(ZPD) theory, and Wood, Bruner, and Ross's (1976) research on tutoring. The term scaffolding was introduced as a metaphor for describing a tutor-child interaction in problem-solving situation by Wood et al. (1976). In the research, scaffolding is conceptualized as a tutor-child interaction process that encourages a child to solve a problem – constructing a pyramidal puzzle. Nonetheless, the concept of scaffolding has been already rooted in Vyotsky's (1962, 1978) socio-historical conceptualization of the development of language and the concept of 'Zone of Proximal Development(ZPD)'. Vygotsky (1962) viewed that humans change themselves through the social communication and interaction, progressing psychological development from an interpsychological to intrapsychological plane. Vygotsky (1978) further defined the ZPD as the distance between a child's "actual developmental level as determined by independent problem solving" and the higher level revealed in "potential development as determined through problem solving under adult guidance or in collaboration with more able peers" (p. 86) (Pea, 2004). Not only that, while the scaffolding concept in Wood et al.'s (1976) research means a prospective mechanism of naturally occurring and informal activities, Vygotsky brought together the informal and the formal, the natural and the designed, concerning human development. In addition, while the ZPD is a conceptual framework regarding selecting appropriate level of learning tasks and support, scaffolding, which originates from the ZPD concept, is a more specified and strategic framework dealing with the 'how to' aspect of such support (Sharma & Hannafin, 2007).

In many cases, scaffolding has been provided through conversational or textual devices such as questions, explanations or feedbacks directly from an instructor or through software devices. Most of the early research focused on such verbal supports from adults or instructors in face-to face learning situation to help learners complete certain tasks (Pearson & Fielding, 1991; Wood et al., 1976). For example, scaffolding is illustrated as providing a cascading sequence of hints (e. g. Brown & Ferrara, 1985; Campione, 1989; Campione & Brown, 1984, 1990; Campione, Brown, Ferrara, & Bryant, 1984), or procedural information and facilitation as learning progresses (e. g. Applebee & Langer, 1983; Scardamalia & Bereiter 1983, 1985), involving several common elements including hierarchical component skills, decreasing support levels, repetitive authentic practice, and ongoing assessment, etc. Consequently, learners become able to have opportunity to extend their current skills and knowledge to a higher level of competence by receiving those instructional supports (Rogoff, 1990). Moreover, in accordance with technological advancement, scaffolding is nowadays viewed to occur among learners and software as well as between learner and instructor (Lumpe & Butler, 2002).

However, the term 'scaffolding' originally represents visually identifiable objects and seems to be opened to any form of modality (Rha & Park, 2010). Therefore, scaffolding can be offered not only in verbal format but also in visual format. Visual scaffolding, in its lexical sense, would be a type of scaffolding which takes diverse forms of visual objects such as diagrams, pictures, or 3D visuals with or without words (Rha & Park, 2010).

According to previous studies, neither verbal nor visual forms of scaffolding is known to be inherently better or worse than the other (Quintana, Krajcik, & Soloway, 2002). That is because diverse forms, means, and types of scaffolding have their own strengths and limitations (Sharma & Hannafin, 2007, Tabak, 2004). For instance, visual scaffolding such as graphical scaffolding would be more effective, powerful, and motivating, while it might also be misleading if designed with less caution. On the other hand, although textual scaffolding is likely to be used well by learners, it is often bypassed because of their textual nature (Quintana et al., 2002). Providing multiple and adaptive supports through diverse means and forms of scaffolding is considered to synergistically support and adaptively meet the varied needs of learners as well (Bull et al., 1999; Tabak, 2004). For example, visual scaffolding can be considered as an equalizer in terms of individual learning style because it diversifies the representational forms of knowledge. In other words, learners who have difficulty in verbal-only or textual-only learning might greatly benefit from visual scaffolding.

Such potentials of visual scaffolding are attributed to the unlimited power of visuals in human learning. Humans incessantly learn by seeing things, actively perceiving and learning from stimuli received from their environment through their eyes(Gibson, 1986). In this vein, the impacts of visuals on learning outcome have long been demonstrated. Previous studies on learning activities using visuals deals with the effectiveness of visual materials, characteristics of visual materials and its educational functions, and the influence of visual materials or visual activities on learning outcome. Those studies reveal that visual activities and materials enhance learners' academic achievement by promoting learners' memorization, understanding, and thinking skills (Park et al., 2010). Besides, visual presentation of contents and learners' visual activities were proven to be more effective than text-only presentation or verbal activities in content abstraction, understanding, organization, and learning (Kashihara & Sttake, 1988; Piburn et al, 2005; Yehezkel, Ben-Ari, & Dreyfus; 2007). In addition, research on the effect of flow charts, meaning maps, diagrams in problem solving and learning has substantiated the potentials of visual representations (Johnson & Satchwell, 1993; Pankratius & Keith 1987; Satchwell, 1997; Stice & Alvarez, 1986).

Although not much, research on visual scaffolding has been existent in various types including content-related pictures or animations (e. g. Gibbons, 2008; Kidwai et al., 2004; Lee, 2007), diagrams or visual organizers (e. g. Coombs, 2006; Cuevas, Fiore, & Oser, 2002; Han, 2006; Lee, 2012; Sung, 2009), structural outlines or silhouettes (e. g. Carrier & Tatum, 2006; Schmidt et al., 2007) analogical or mnemonic visuals (e. g. Quintana et al., 2002; Rha & Park, 2010) and even hand and arm gestures of an instructor (e. g. Alibali & Nathan, 2007). According to those research results, visual scaffolding seems to have positive effects on learning in various ways. First, visual scaffolding would better represents and emphasizes information providing more powerful affordance derived from its visual nature, effectively attracting learners' attention and helping their understanding. Second, visual scaffolding would implicitly provide supplementary information from its visual image, such as tacit hints or visual cues. Third, visual scaffolding promotes more holistic understanding of tasks or contents by spatially representing macro-views.

Despite that previous studies imply the effectiveness and potentials of visual scaffolding, it still receives insufficient academic attention than verbal scaffolding and the research on visual scaffolding tends to be sporadic and fragmental. There has rarely been a systematic approach on what visual scaffolding is, how it works, and what effects it would lead to, and so on. In this respect, this research aims to conduct a literature review on the types, effectiveness, and further potentials of visual scaffolding in teaching and learning perspectives. Such work might contribute to providing a more systematic approach and comprehensive view on visual scaffolding for teaching and learning.

Studies on Visual Scaffolding

For conducting a literature review on visual scaffolding, the process of search, selection, analysis, and synthesis was gone through. In search phase, the author used several databases such as ERIC, Springerlink, Jstore, Sciencedirect, Google scholar, and Seoul National University Online Library to search books, articles, and other relevant resources regarding visual scaffolding, visualization, scaffolding, and so on in accordance with Bidwell and Jensen's (2003) method and Gall, Borg, and Gall's (1996) method of identifying sources of information. In selection, analysis, and synthesis phase, the author conformed to Hart's (1998) method of doing a literature review. For selection, the author sorted out related literature in accordance with the criteria of authority, seminality, and relevancy. Next, for analysis, chosen literature was categorized into its sub-areas, the main results were summarized and organized, and the analysis on the critical points was carried out. Last, for synthesis, the results of examined studies were categorized, organized, and summarized.

Visual scaffolding in diverse fields

The term "visual scaffolding", and the strategy of visual scaffolding have long been used in various fields. Visual scaffolding has been used in computer science, visual design, geography, etc. In such fields, visual scaffolding has been mainly employed for displaying contents in more effective way and supporting and guiding users to better understand, operate, and create complicated data, information, and objects.

In computer science, visual scaffolding has been used as a tool for data visualization. Researchers have designed visual scaffolding which displays data structure more effectively, by visually showing linked or related data, zooming a specific part of visualized data for more detailed view, or merging and mapping several data structures as shown in Figure 1 (Lee & Urlich, 2011). Visual scaffolding has been also devised as a software visualization tool to permit students to think and see their programming process in terms of data structures and algorithms by showing student's programming outputs and corresponding errors step-by-step (Charles & Eugene, 2001). Not only that, in visual design field, visual scaffolding usually means aids for techniques for compute-based sketching or designing by providing various technical supports: structural outline, construction lines, silhouettes of the objects (Schmidt et al., 2007). Those visual scaffoldings help designers to understand complicated 3-D scenes and rapidly conceptualize and edit 3-D visuals using non-photorealistic rendering and simplified contours or sketch drawings (See Figure 2) (Zeleznik, Herndon, & Hughes, 2007). In geology, visual scaffolding has been often used to facilitate interpreting real-world spatial relationships from traditional two-dimensional maps. It is because it becomes easier to identify and examine certain geological features by providing pictorial representations of relevant features as visual scaffolding. It has been reported that incorporating virtual 3-D visual scaffolding, as displayed in figure 3, could solve the cognition problem hampered by incomplete exposure of all spatial dimensions by promoting geological cognition performance (Whitmeyer et al., 2009). Moreover, it has been reported that user's geological performance tends to be more accurate when visual scaffolding is provided in their geological operations (Mayer, Mautone, & Prothero, 2002).

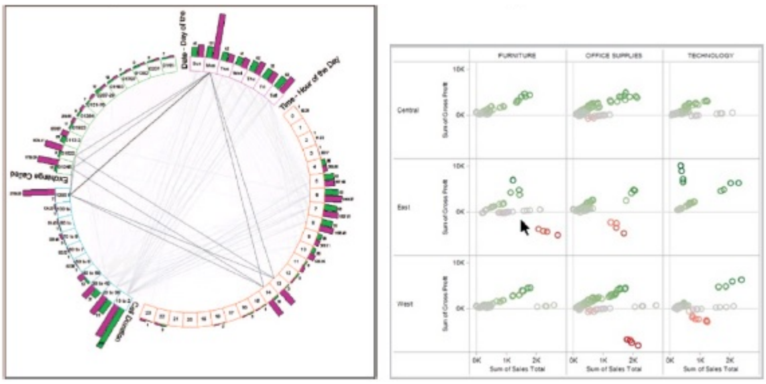

Figure 1. Visual scaffolding for data visualization (Lee & Urlich, 2012)

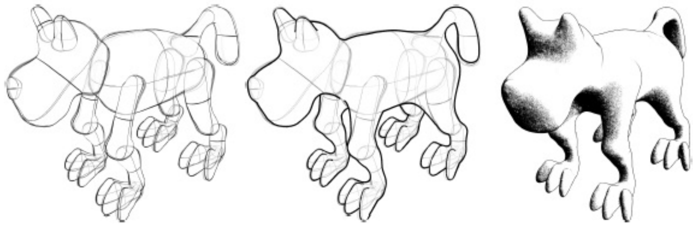

Figure 2. Visual scaffolding for a computer-based drawing (Schmidt et al, 2007)

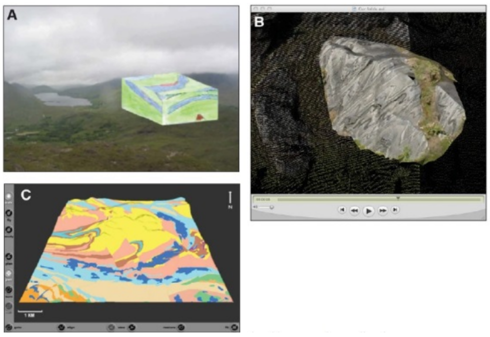

Figure 3. Visual scaffolding for a cognition performance (Whitmeyer et al., 2009)

Although existent and widely mentioned, research on visual scaffolding in various fields still seems to be rather scattered and fragmental, lacking in theoretical consensus of visual scaffolding, in terms of the concepts, types, mechanisms, effectiveness, design strategies, and so on.

Visual scaffolding in teaching and learning

Research on visual scaffolding has mostly employed visual objects such as graphic organizer, pictures, diagrams, abstract visuals, and even hand and arm gestures in order to enhance learning efficiency and effectiveness.

According to previous studies, visual scaffolding seems to promote learning by providing both implicit and explicit hints. Quintana et al.(2002) used graphical scaffolding to support learners by providing big picture or macro view of science inquiry learning as shown in Figure 4. They reported that learners happened to be offered tacit hints from visual scaffolding which suggest the clockwise order of problem-solving process through the shape of a wheel. In similar vein, Rha and Park (2010) examined the effectiveness of procedural visual scaffolding by analogizing the problem solving process to a process of drawing person's face and spatially representing it as visual scaffolding (See Figure 5). Such visual scaffolding is assumed to implicitly offer tacit hints for the problem solving phases as well as explicitly work as a mnemonics for the problem solving phases. Additionally, visual scaffolding is actively used as explicit aids for language learners in that it encourages knowledge comprehension by supplementing verbal information through visual images. Language learners can have difficulty understanding verbal-oriented text when learning other language or subjects. Therefore, pictures, drawings, illustrations, graphic organizers, and other visuals have been widely used as visual scaffoldings. Those visual scaffoldings are known to improve language learning, and even to overcome cultural difference. Gibbons (2008) also demonstrated the effectiveness of visual scaffolding for English-mediated science class students who use English as second language. He used simultaneous displays of drawings and photographs related to the science contents as visual scaffoldings, concluding that the visual scaffolding seems to serve as a non-linguistic representation of science concepts. Last but not least, visual scaffolding such as a graphic novel is known to be

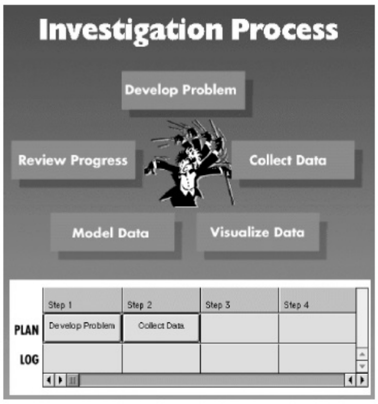

Figure 4. Visual description of inquiry activities (Quintana et al., 2002)

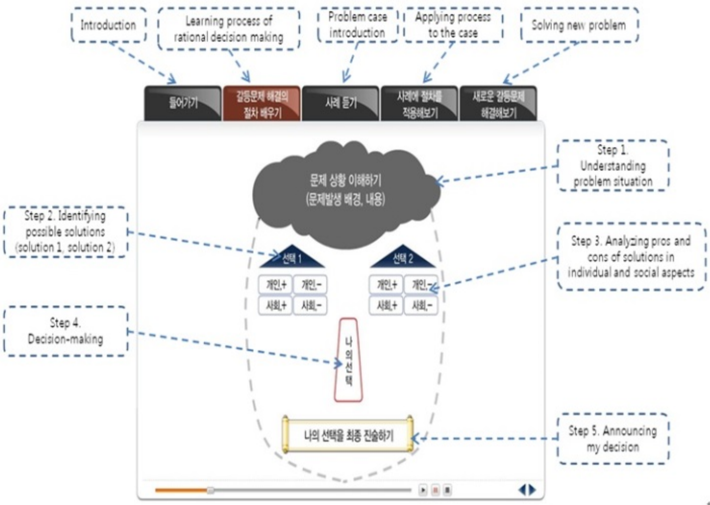

Figure 5. Analogy of problem solving (Rha & Park, 2010)

entertaining to and especially effective for visual learners and struggling readers, as they combine images with text to increase comprehension (Hassett & Schieble, 2007).

Other studies reveal the potentials of visual scaffolding in terms of cognitive load and learning efficiency. Cuevas et al.'s (2002) research utilizes diagram as visual scaffolding to catalyze learners' cognitive process. They reported that the diagram scaffolding supported learners' mental model formation, thus significantly improving the instructional efficiency in complex task training environment by diminishing cognitive load (See Figure 6). Moreover, they maintained that the diagram scaffolding is effective for the acquisition of integrative knowledge than declarative knowledge. Not only that, Quintana et al.(2002) also additionally reported that the visual scaffolding played a central role in encouraging students' metacognition and comprehensive understanding of the given task. As shown in Figure 7, the 'Conductor Window' illustrates metaprocess activities such as what activities are possible, what steps to take next in the investigation, and so on. Kidwai et al. (2004) designed high and low level visual scaffolding for higher order learning, describing the visual scaffolding at the conceptual level: simple scaffolding

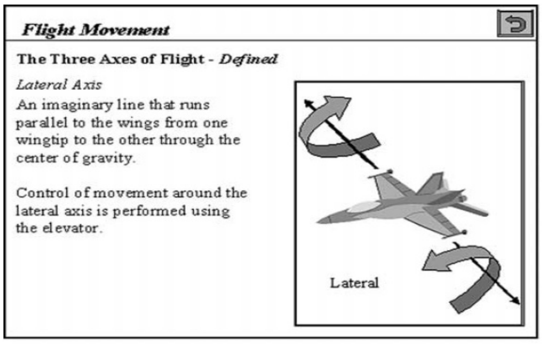

Figure 6. Diagram scaffolding (Cuevas et al., 2002)

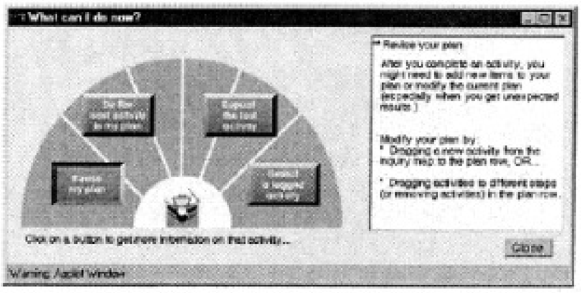

Figure 7. Conductor window (Quintana et al., 2002)

instigates lower levels of cognitive processing in learners as compared to complex scaffolding which instigates higher levels of cognitive processing in learners. They assumed that the visual scaffolding diminishes cognitive load by enabling learners to focus on the critical features. Their research argues that visual scaffolding, if specifically designed and appropriately employed, would have potentials for emphasizing and illustrating procedural understanding, decreasing the cognitive load associated with higher order learning. In similar manner, visual scaffolding seems to provide visual cues for elaborating and highlighting important information. Alibali and Nathan (2007) considered teachers' hand and arm gestures as forms of visual scaffolding. They reported that teachers used gestural scaffoldings most frequently for critical information, new and unfamiliar materials, abstract referents, etc. Furthermore, such gestures were assumed to function as grounding teachers' verbal instruction to connect the teachers' verbal explanation with real-words and physical referents, thereby enabling students to process information through both verbal and visual channel. Carrier and Tatum (2006) used 'sentence wall', which visually reorganized and rearranged text into more grammatically-structured visual shapes and implied the effects of visual scaffolding on text comprehension, by lessening cognitive load. Besides, as displayed in Figure 8, Coombs (2006) used visual learning templates such as a spidergram as a visual scaffolding to develop English learners' critical thinking skills. In his research, learners were supposed to manifest those visual templates as their psychological schemas or a mental model for higher-order thinking.

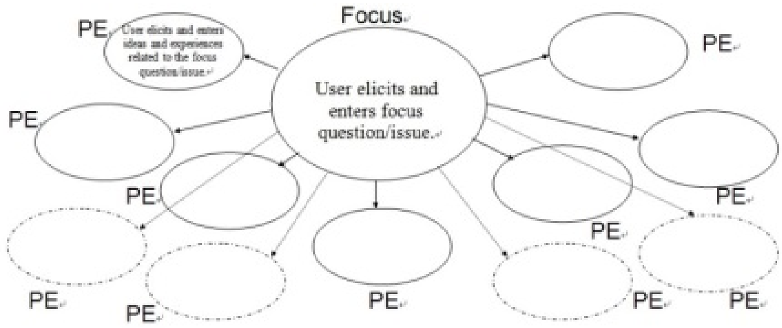

Figure 8. Visual learning template (Coombs, 2006)

Besides, although not using the exact term of 'visual scaffolding', studies on the visualization of texts imply the potential of visual scaffolding. Research on visual organizer, visual imagery, visual transformation of text are the examples (e. g. Han, 2006; Jin, 2009; Lee, 2007; Lee, 2012; Sung, 2009). Those studies aim at enhancing text comprehension by visually displaying and representing learning contents. To illustrate, visual organizers are widely employed as both mathemagenic organizer and semantic organizer. Lee's (2012) visual summarizer is a semantic organizer which summarizes and represents content through a graphic organizer (See Figure 9). On the other hand, mathemagenic visual organizers provide visual overview of the text by physical and mechanical reduction and abstraction of the text. As reduction strategies, thumbnail type of visual overview is used to provide spatial and physical information of text (e. g. Han, 2006; Shin, 2006; Sung, 2009). Moreover, Han (2006) developed and utilized mathemagenic and mechanical visual organizer which contains spatial and physical information of the text amount, structure, outline, and main point in visually abstracted format through visual cues such as geometric geometrical figures, colors, symbols, and icons (See Figure 10). Not only that, transforming the visual elements of text such as size, shape, color in a way that coincides with the content and learners' way of thinking is proved to catalyze text comprehension as well (Jin, 2009). Studies on the kinetic typography are typical examples of such visual transformation of text (e. g. Ford, Forlizzi, & Ishizaki, 1997; Forlizzi, Lee, & Hudson, 2003; Ishizaki, 1996). Besides, there are not only final form visual scaffolding but also participatory visual scaffolding. Lee's (2007) visual imagery strategy which encourages learners to freely imagine and associate content-related visual images during the learning phase and Coombs' (2006) visual learning templates are the examples of such participatory visual scaffolding which actively engages learners visual representation of learning content.

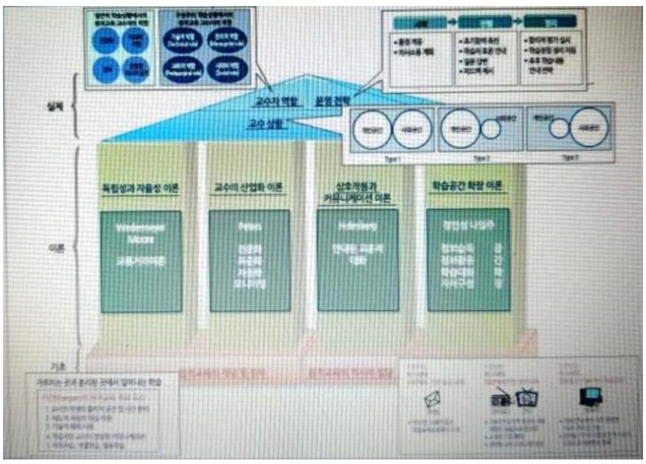

Figure 9. Visual summarizer (Lee, 2012)

Figure 10. Visual organizer (Han, 2006)

Types of Visual Scaffolding

Visual scaffolding would be categorized into content-independent type and content-dependent type. Furthermore, visual scaffolding can be classified by its visual types as well: abstract-verbal one, concrete-verbal one, concrete-visual one, and abstract-visual one.

Categorization by content independency/dependency

Content-independent visual scaffolding

Visual scaffolding can deal with content-independent area of learning in many ways. One type of content-independent visual scaffoldings can be highlighting important parts of contents by changing the text format such as color, size, and font or by underlining, using kinetic typography and so on. For example, in Sung's (2009) research, visual scaffolding highlights important passages, words, or sentences in different color to draw learners' attention on the gist of the text. Similarly, Park (2010) used visual scaffolding which highlights learning problem-solving phase using different color as learners proceed problem-solving procedure step-by-step. Not only that, In Alibali and Nathan's (2007) research on gesture scaffolding, Han's (2006) research on visual organizer, and Jin's (2009) study on visual transformation of digital text, visual scaffoldings such as finger-pointing, marking, and inserting kinetic typography are used for highlighting critical points of contents.

Another type of content-independent visual scaffolding exists. According to Hannafin, Land, & Oliver (1999) and Hannafin et al., (2001), strategic and metacognitive type of scaffoldings can assist learners in terms of 'how and what to think' and 'how to use appropriate strategies' at key-phases of learning while conceptual and procedural scaffolding facilitate learners with more content-related hint and guidance. For example, prompting reflective questions or offering advice related to learning strategy or self-management skills are metacognitive or strategic scaffolding. Still, this type of visual scaffolding rarely exists in that such visual scaffolding might mislead learners in accordance with each individual's different assumption about various visual cues and shapes. That is why visual scaffolding for generic guidance and hints is hard to be realized in visual-only format.

Last but not least, visual scaffolding can provide information regarding the physical structure of text. Mechanical visual scaffolding used in Han's (2006) study shows spatial and physical information of text by abbreviating text contents through geometrical figures, colors, symbols, and icons (See Figure 10, 11). On the other hand, Sung (2009) employed thumbnail as a visual organizer as displayed in

Figure 11. Thumbnail matrix as visual organizers(Sung, 2009)

Figure 11. Such thumnails can also help learners grasp macro view of contents easily, encouraging comprehensive and structurual understanding of contents and lessening cognitive load.

Content-dependent visual scaffolding

Content-dependent visual scaffolding provides supports for understanding concept, procedure, and principle. According to Merrill's (1983) component-display theory(CDT), content types are classified into fact, concept, procedure, and principle. Combining the CDT with Hannafin et al.'s (1999, 2001) categorization of scaffolding, the target of content-dependent visual scaffolding can be concept, procedure, and principle. – The 'fact' component of Merrill's (1983) CDT and the 'strategy' and 'metacognition' component of Hannafin et al.'s (1999, 2001) are excluded because the former is mainly related to rote-identity operation and the latter to content-independent type of support.

Concept indicates symbols, events, and objects that share characteristics and are identified by the same name (Merrill, 1983). Therefore, when the target of visual scaffolding is a concept, the visual scaffolding supports learners in identifying key conceptual knowledge or in structuralizing conceptual organization of the learning content, leading learners to have content-relevant perspectives and to consider critical aspects and elements of the content (Hannafin et al., 1999). Visual summarizer (e. g. Lee, 2012), which displays the gist of learning content through visuals can be considered as a type of concept-related visual scaffolding in that it supports learners in text comprehension by visually displaying and representing and the main point and structure of the contents (See Figure 9, 12). Other examples of conceptual visual scaffolding are prevalent in instructions mediated by second language. Because learners who participate in second-language-mediated instructions can have difficulty in understanding, verbal-oriented information, pictures, visual organizers, and other types of visual representations of concept are widely employed as visual scaffolding strategies (e. g. Coombs, 2006; Gibbons, 2008). Moreover, instructors' hand and arm gestures used to elaborate content concept are examples of visual scaffolding as well (e. g. Alibali & Nathan, 2007).

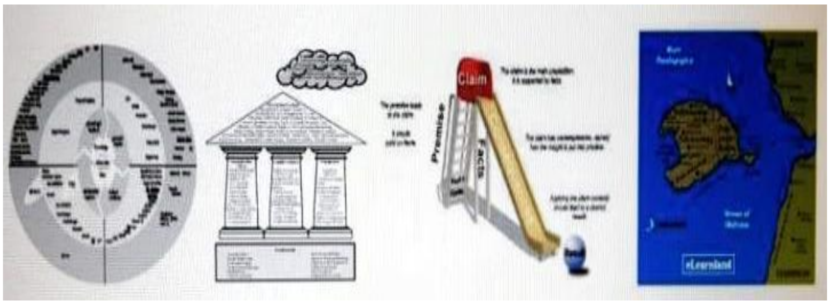

Figure 12. Visual metaphors for concept learning (Lee, 2012)

Secondly, as procedure means a set of ordered steps, sequenced to solve a problem or accomplish a goal (Merrill, 1983), procedural visual scaffolding is intended to support learners in grasping steps. To illustrate, Quintana et al. (2002) utilized visual scaffolding which suggests the task process implicitly. Their research demonstrated that learners apparently obtained implicit hints about learning process from the visual shapes (See Figure 4, 7). Not only that, Rha and Park's (2010) visual scaffolding supported learners to grasp the problem-solving process by providing mnemonic visual, a person's face, as an analogy of the problem-solving process as shown above in Figure 5.

Thirdly, as principle explains why or how something happens or works in a particular manner, visual scaffolding on principles enables learners to more easily understand mechanism-related contents. To be specific, visual scaffolding used in Kidwai et al.'s (2004) research assisted learners in understanding the mechanism of human's heart. In the similar manner, visual scaffolding in Cuevas et al.'s (2002) research elaborated how aircraft is operated by utilizing diagrams. Not only that, visual scaffolding which provides content-related strategy or metacognitive help also promotes learners in terms of principles for the task accomplishment (See Figure 6).

Categorization by types of visuals

Visual scaffolding can be classified by its visual types along with two continua: concrete-abstract(icon-digital) continuum (Wileman, 1993) and visual-verbal continuum (Miller, 1987; Doblin, 1978; Wileman, 1980). A 2 x 2 matrix can be formulated by crossing these two continua as follows (See Figure 13).

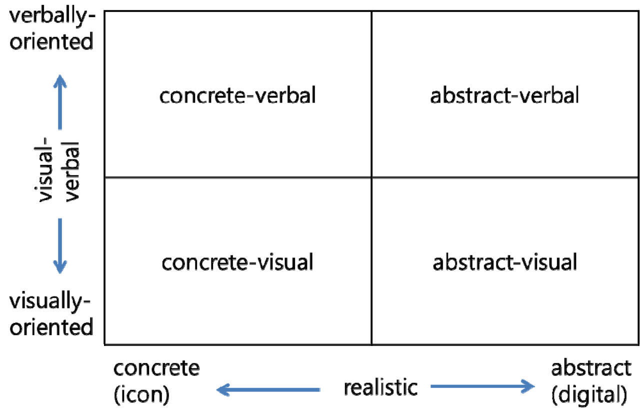

Figure 13. Types of visuals

The abstract-concrete continuum is based on the continuum of visual reality, anchored at one end by the abstract(digital) and at the other by the concrete(iconic). This abstract-concrete continuum has been widely employed by scholars to explain human's thinking process or instructional materials. Explaining human's thinking process, *Rha (2003)* has suggested that human stores abstract form of information through abstraction process as they repeatedly experience concrete objects. On the other hand, to categorize message, *Doblin (1978)* classified verbal message and visual message, further suggested six types of visual message from abstract to concrete one: marks, chart and graphs, drafting and maps, drawing, photographs, and models. According to Doblin (1978), the most realistic visual message is a model which is realized three-dimensionally, whereby the least realistic one is a symbolically abstract marks.

The visual-verbal continuum represents the degree of verbal-visual use. Wileman (1993) suggested a continuum at one end of which being purely visual and at the other end of which being purely verbal, presenting seven image types: pictorial or graphic symbol frame(purely visual), emphasized pictorial or graphic symbol frame, pictorial or graphic symbol frame with verbal cues to meaning, verbal/visual balanced frame, reader frame with visual cues to meaning, emphasized reader frame, and reader frame(purely verbal). These seven types are divided in accordance with the degree of verbal and visual use. Han (2006) also divided visual organizer into visually-dominated organizer to verbally-dominated organizer and Braden (1994) classified graphics into visually-dominated one and verbally-dominated one as well. According to the Braden's (1994) classification, in visually dominated graphics, the purpose of verbal symbols is merely to point out part of the whole content or to provide some clue for interpreting the visual message; in verbally-oriented graphics, the verbal symbols usually contains most of the message and the visual elements exist to enhance the display of the message. In visually-oriented visual scaffolding, the function of verbal symbols is to facilitate the language deficiency of images. On the other hand, in verbally-oriented visual scaffolding, visuals are provided for better display of message.

Abstract-verbal visual scaffolding

As displayed in the matrix, the first type of visual scaffolding is abstract-verbal. Numerous types of content-dependent visual organizers might be the example of this type. For example, graphic organizers which contain main point of the content in verbal format can function as visual scaffolding. Lee 's (2012) visual summarizer (See Figure 9, 13), Carrier & Tatum's (2006) sentence-wall visual scaffolding, Visual transformation of text(e. g. Jin, 2009) are the examples in that they actively utilize verbal messages as main information source and abstract visual symbols are used as supplementary tools and implicit hints (See Figure 14).

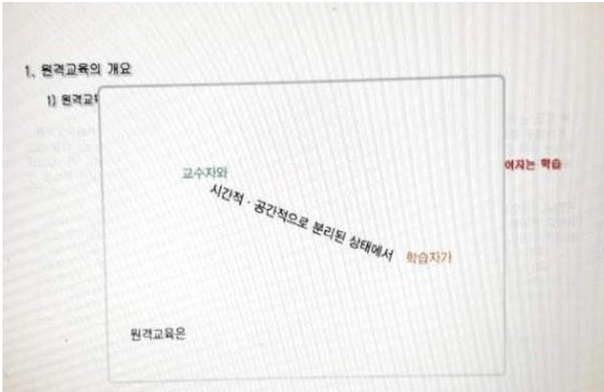

Figure 14. Visual transformation of texts (Jin, 2009)

Concrete-verbal visual scaffolding

The second type is concrete-verbal visual scaffolding. A typical example of this type might be the use of thumbnails as mechanical visual scaffolding (e. g. Han, 2006; Sung, 2009). Although those visual scaffoldings are extremely concrete in that they are physical reduction of the actual digital text, those scaffoldings do not actively contain visual images or illustrations (See Figure 10, 11).

Concrete-visual visual scaffolding

The next type of visual scaffolding is concrete-visual one. Using pictures, drawings, or imageries for scaffolding would be the example for this type. In Gibbons's (2008) research photographs, drawings, illustrations of the learning contents are provided as visual scaffolding. Furthermore, encouraging learners' to imagine and associate content-related visual imageries might be this type of visual scaffolding. Not only that, Schmidt et al.'s (2007) visual scaffolding belongs to this type in that they provide a sketch of real objects as scaffolding (See Figure 2).

Abstract-visual visual scaffolding

The last type is abstract-visual visual scaffolding. The best example of this type is the visual scaffoldings which employ mathemagenic visual organizers based on abstraction principle as realized in Han(2006)'s study. The mechanical visual scaffolding used in Han's (2006) research does not contain any verbal message and consists of abstract symbols, geometric figures, etc (See Figure 10, 11). Although the visual scaffolding is purely visual, it is extremely abstract in that it is full of symbolic visuals.

Visual scaffoldings which belong to somewhere middle in the matrix exist as well. Rha and Park's (2010), Kidwai et al.'s (2004), Quevas et al.'s (2002) visual scaffoldings are the cases. Rha and Park's (2010) visual scaffolding, as displayed in Figure 5, might belong to somewhere in the middle of type III and type IV. That is because, although their visual scaffolding is purely visual in that it does not contain any verbal message, it is neither entirely concrete nor entirely abstract. Kidwai et al.'s (2004) and Quevas et al.'s (2002) visual scaffolding might be placed between type I and type IV (See Figure 6). Because, although their visual scaffoldings are abstract in that they used symbolic visuals, they mixed visual and verbal message together in order to explain mechanisms more effectively and efficiently.

Discussion

Visual scaffolding and its effectiveness

Overall, visual scaffolding would be regarded as a support using diverse forms of visual objects from abstract symbols to concrete pictures with verbal or visual explanation aiming to enable learners to accomplish tasks which would be beyond their task. Such visual objects can not only be represented, but also be structuralized, analogized, and transformed to suggest richer information, providing macro view of task or information, or highlighting critical feature to facilitate the momentum for better thoughts, insights and more structural and in-depth understanding in learning.

The effects of visual scaffolding might be explained in three aspects. First, visual scaffolding seems to explicitly represent and highlight information both effectively and efficiently. To begin with representational and interpretive visuals can visually re-phrase and emphasize parts of textual explanation in various ways. This merit of visual scaffolding would be explained through Paivio's dual coding theory as well. According to Paivio(1971, 1986), human perceives and encodes information through verbal and visual channel and the verbal and visual systems are stored in long-term memory through referential connection. Such dual processing of information optimizes the use of working memory which has a limited capacity. Empirical research also shows that providing visual information is effective for learning in practice(Mayer, 2001; Mayer & Anderson, 1991, 1992; Mayer, Bove, Bryman, Mars, & Tapangco, 1996). Not only that, visual scaffolding would emphasize critical or structural features. This is because visual scaffolding might be more powerful affordance thanks to its visual nature, attracting and directing learners' attention and selectively highlight essential or skeletal parts of contents utilizing organizational or transformational visuals. Alibali and Nathan's (2007) gesture scaffolding, visual cues used for highlighting in Han's (2006) study, Rha and Park's (2010) shading strategy for important text, and Jin's (2009) use of kinetic typography for key points of text are the examples. By visually differentiating and distinguishing important parts of learning content, visual scaffolding enables learners to learn more effectively and efficiently. Furthermore, visual scaffolding in Schmidt et al. (2007)'s research provides only skeletal information of objects such as silhouettes for helping users to complete the full design of the objects. Consequently, users could grasp macro view of objects, consequently more easily completing their design tasks.

Second, visual scaffolding would provide richer information in implicit way as well. Visuals cannot help naturally providing some additional information while displaying the visual image itself. Shape, space, direction, structure, relationship, size and color are all the supplementary information inherent in the visual image (Rha and Park, 2010). For example, Quintata et al. (2002), and Rha and Park (2010) stated that the shape of visuals seems to be a tacit hint for accomplishing the given task. Lee (2012) also stated that providing a visual organizer that summarizes preceding texts or instructions encourages learners to implicitly acquire new information although not explicit in the text because the shape of visual summarizer supported learners' reasoning process. Jin's (2009) visual transformation of text, Carrier and Tatum's (2006) are also the example. Likewise, though not written in verbal terms, pieces of information are scattered in the shape and the space of visual scaffolding. Even if the message is not explicit, learners' assumptions of the specific shapes or forms of given visual scaffolding seem to function as additional information about the task (Quintana et al., 2002). Such additional visual aid would subsequently promotes more insightful perspectives, in-depth understanding, and higher order thinking as well(Buzan, 1994; Lee, 2012; Okebukola, 1992; Quintana et al., 2001; Rha & Park, 2010).

Third, providing visual scaffolding of the structure or process might lead learners to understand the overall information with less cognitive load. This is mainly because the external visual representation of the task may facilitate learners to form internal representation and coherent mental model (Cuevas et al., 2002; Jonassen & Hung, 2006; Lee, 2012). Studies report that the visual scaffolding might especially support learners' higher order thinking by lessening their cognitive load (e. g. Cuevas et al., 2002; Han, 2006; Kidwai et al., 2004; Rha & Park, 2010) and facilitate their holistic and structural understanding of the task or content structure, thus promoting systematic and integrated comprehension (e. g. Cooms, 2006; Han, 2006; Lee, 2012; Rha & Park, 2010). Schwartz and Heiser(2005) argued that learners understand particular knowledge structure effortlessly if they are provided with spatial representation about the content structures. On top of that, such functions of visual scaffolding might also be related to mental model theory. Human is known to construct his own understanding of how things work, and what will happen by interpreting visual structure of objects (Norman, 1986). Furthermore, such a mental model is known to be formed through experience, training, and instruction rather than developed inherently (Norman, 1988). In this manner, visual scaffolding shown to learners would encourage them to build their mental model more easily.

Technology and further potentials of visual scaffolding

In today's visual media-driven society, digital visuals and visual scaffoldings which are provided and mediated by technological artifacts are extensive. In terms of such visual scaffoldings, some critical considerations can be raised.

First, the visual scaffolding provided through software-system-only hardly utilizes human agency with which learners can interact (Pea, 2004). Without such social interaction with human, learners might have difficulty in sense-making, emotional control, or even grasping the key points of learning. More importantly, non-human devices may not function effectively for calibrated and adaptive supports in accordance with ongoing assessment of learners' level. Shrein et al. *(2004)* also pointed out that interactive tuning - such as the selection and calibration - of scaffolding, which is pivotal in scaffolding concept - is uneasy through technological–artifact-only scaffolding. In similar vein, mentioning the importance of 'human' elements in terms of fading, Pea (2004) stated that extant practices of scaffolding through technological artifacts which lack 'fading' component of scaffolding might be a distributed intelligence rather than scaffolding-with-fading. In this manner, bringing together technological artifacts and human's scaffolding activities effectively is necessary and urgent. Tabak's (2004) research on distributed scaffolding might be an example which utilizes technology in harmony with human's scaffolding. Criticizing that numerous software scaffoldings are lacking in social interaction between instructor and learner, Tabak (2004) suggests distributed scaffolding called "synergy" as an ideal type of scaffolding. In "synergy", learners accomplish a specific task using software system while constantly receiving instructor's adaptive and immediate guidance as scaffolding. In this way, learners seem to demonstrate higher level of performance. Such an integrative use of technology and human might contribute to learning, mirroring the original concept of scaffolding.

Second, visual scaffolding mediated by technological artifact can be extended to an intelligence amplifier. Relating scaffolding-with-fading to distributed intelligence, Pea (2004) suggests significant direction for utilizing scaffolding to augment human intellect, citing Engelbart's (1962) report which created a new framework for the relation between computing and human thinking and activity.

> *Symbols can be arranged before human's eyes, moved, stored, recalled, operated upon according to extremely complex rules - all in very rapid response to a minimum amount of information supplied by human, by means of special cooperative technological devices. In the limit of what we might now imagine, this could be a computer, with which we could communicated rapidly and easily, coupled to a three-dimensional color display within which it could construct extremely sophisticated images with the computer being able to execute a wide variety of processes on parts or all of these images in automatic response to human direction. The displays and processes could provide helpful services and could involve concepts not hitherto imagined. (p.25)*

Likewise, as Pea (2004) asserted the potential of scaffolding to be an intelligence amplifier, visual scaffolding also might extend its possibility in a way that enhances human's intellect.

Conclusion

Visual scaffolding would be regarded as a support using diverse forms of visual objects from abstract symbols to concrete pictures with verbal or visual explanation aiming at learners' task accomplishment. Visual scaffolding would be either content-independent or content-dependent visual objects which can be on both the abstract-concrete continuum and the visual-verbal continuum. Such visual scaffolding can represent and highlight contents in more effective way, suggest richer implicit information, and provide macro view, thereby offering the momentum for better in-depth understanding, thoughts, and insights. Furthermore, visual scaffolding might extensively enhance and amplify learning through appropriate utilization of technological advancement.

The limitations of this study are as follows. First, although this research put together research on visual scaffolding in teaching and learning field, the study could not elucidate the actual mechanism of visual scaffolding and the effective way of visual scaffolding design. Second, this research is confined to literature review because it aimed to synthesize the extant discourse of visual scaffolding. Therefore, this study lacks in more authentic context. Third, this research mainly deals with visual scaffolding in teaching and learning aspect. Although visual scaffolding is widely applied in other areas, such macro perspectives could not be comprehensively included well in this study.

Following suggestions can be made for further development and utilization of visual scaffolding. To begin with, efforts to clarify the 'how' aspect of visual scaffolding are needed. Inquiries such as 'Where does the effectiveness of visual scaffolding stems from?', 'How does the visual scaffolding support learners?' should be raised and examined more rigorously (Rha & Park, 2010). Not only that, comprehensive and systematic models, strategies, principles, and guidelines for visual scaffolding design are needed. Concerning the high potentials of visual scaffolding, professionals in teaching and learning field need to explore appropriate methods for designing visual scaffolding, starting from the prototypical design of visual scaffolding. Next, more quantitative and qualitative study needs to be conducted to demonstrate the effectiveness and efficiency of visual scaffolding. Last but not least, research on the applications of enhanced technology for visual scaffolding is necessary. Today's advanced and high technology seems to shed light on more effective and visual scaffolding in innovative ways. Such research would lead to a different phase of visual scaffolding for teaching and learning.

References

Alibala, M., & Nathan, M. J. (2007). Teachers' gestures as a means of scaffolding students' understanding: Evidence from an early algebra lesson. In R. Pea, B. Barron, & S. J. Derry (Eds.), *Video Research in the Learning Sciences.* Mahwah, NJ: Erlbaum.

Applebee, A. N., & Langer, J. A. (1983). Instructional Scaffolding: Reading and writing as natural language activities. *Language Arts, 60*, 168-175.

Bidwell, S., & Jensen, M. F. (2003). Chapter 3: Using a search protocol to identify sources of information: the COSI model. *Etext on Health Technology Assessment (HTA) Information Resources [Internet]. Bethesda: US National Library of Medicine, National Institutes of Health, Health* & *Human Services*.

Braden, R. A. (1994). Visual verbal relationships. *Visual literacy: A spectrum of visual learning*, 193-208.

Brown, A. L., & Ferrara, R. (1985). Diagnosing zones of proximal development. In J. Wertsch (Ed.), *Culture, communication, and cognition: Vygotskian perspectives* (pp. 273-305). Cambridge, England: Cambridge University Press.

Bull, K. S., Shuler, P., Overton, R., Kimball, S., Boykin, C., & John, G. (1999). *Processes for developing scaffolding in a computer mediated learning environment.* Paper presented at the American Council of Rural Special Education(ACRES) conference, Albuquerque, New Mexico.

Campione, J. C. (1989). Assisted assessment: A taxonomy of approaches and an outline of strengths and weaknesses. *Journal of Learning Disabilities, 22*, 151-165.

Campione, J. C., & Brown, A. L. (1984). Learning ability and transfer propensity as sources of individual differences in intelligence. In P. H. Brooks, R. Sperber, & C. McCauley (Eds), *Learning and cognition in the mentally retarded* (pp. 265-293). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Campione, J. C., & Brown, A. L. (1990).Guided learning and transfer: Implications for approaches to assessment. In N. Frederiksen, R. Glaser, A. Lesgold, & M.

Shafto (Eds.), *Diagnostic monitoring of skill and knowledge acquisition* (pp. 141-172). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Campione, J. C., Brown, A. L., Ferrara, R. A., & Bryant, N. R. (1984). The zone of proximal development: Implications for individual differences in learning. In B. Rogoff& J. V. Wertsch (Eds.), *New directions for child development: No. 23: "Children's learning in the zone of proximal development"* (pp. 77-91). San Francisco, CA: Jossey Bass.

Carrier, K. A., & Tatum, A. W. (2006). Creating sentence walls to help English language learners develop content literacy. *The reading teacher, 60*(3), 285-288.

Charles, F. K., & Eugene, R. T. (2001). Active visual scaffold. *First International Program Visualization Workshop.* pp. 179-192.Porvoo, Finland: University of Joensuu Press.

Coombs, S. (2006) Engaging Learners through Critical Thinking Scaffolds. *The MirandaNet Braided Learning e-Journal, MirandaNet Fellowship.* Downloaded from: http://www.mirandanet.ac.uk/cgi-bin/journals/search_ej.pl?runtype=news; ejtype=ins, 1.11.07.

Cuevas, H. M., Fiore, S. M., & Oser, R. L. (2002). Scaffolding cognitive and metacognitive processes in low verbal ability learners: Use of diagrams in computer-based training environments. *Instructional Science, 30*, 433-464.

Doblin, J. (1987). A short, grandiose theory of design. *STA Design Journal, Analysis and Intuition*, 6-16.

Engelbart, D. C. (2001). Augmenting human intellect: a conceptual framework (1962). *PACKER, Randall and JORDAN, Ken. Multimedia. From Wagner to Virtual Reality. New York: WW Norton & Company*, 64-90.

Ford, S., Forlizzi, J., & Ishizaki, S. (1997). Kinetic typography: Issues in time-based presentation of text. *CHI'97 Conference Extended Abstracts,* pp. 269-270.

Forlizzi, J., Lee, J., & Hudson, S. (2003). The kinedit system: Affective messages using dynamic text. *Proceedings of CHI 2003* (pp. 377-384). Fort Lauderdale, FL: ACM Press.

Ishizaki, S. (1996). Multi-agent model of dynamic design: Visualization as an emergent behavior of active design agents. *Proceedings of the SIGCHI conference on Human factors in computing systems: common ground* (pp. 347-354). ACM.

Gall, M. D., Borg, W. R., & Gall, J. P. (1996). *Educational research: An introduction*. Longman Publishing.

Gibson, J. J. (1986). *The ecological approach to visual perception.* Hillsdale, NJ: Lawrence Erlbaum Associations.

Han, A. (2006). *Design and utilization of the visual organizers in web-based learning. (Unpublished doctoral dissertation).* Seoul National University, Seoul, Korea.

Hannafin, M., Land, S., & Oliver, K. (1999). Open learning environments: foundations, Methods, and Models. In K. Hogan & M. Pressley(Eds). *Scaffolding student learning: instructional approaches and issues* (pp.115-140). Cambridge, MA: Brooklyne Books.

Hannafin, M. J., McCarthy, J. E., Hannafin, K. M., & Radke, P. (2001). Scaffolding performance in EPSSs: Bridging theory and practice. *Proceedings of 2001 ED-MEDEA World Conference on Educational Multimedia, Hypermedia,* & *Telecommunications,* 658-663.

Hart, C. (1998). *Doing a literature review: Releasing the social science research imagination.* Sage.

Hassett, D. D., & Schieble, M. B. (2007). Finding space and time for the visual in K-12 literacy instruction. *The English Journal, 97*(1), 62-68.

Kashihara, A., & Satake, Y. (1998). *A history visualization for learning-by exploration in hypermedia on WWW.* Proceedings of Webnet 98 World Conference of the WWW, Internet and Intranet (3rd, Orlando, FL, November 7-12), 9-17.

Kidwai, K., Mynuofu, M., Swain, W. J., Ausman, B. D., Lin, H., & Dwyer, F., (2004). *Effect of visual scaffold and animation on students performance on measure of higher order learning.* Paper presented at the selected research and development presentations at the national convention of the Association for Educational Communications and Technology(AECT), Chicago, IL.

Lee, S., & Urlich, N. (2011). A meta-notation for data visualization. *Visualization and Data Analysis 2011*, 7868, 78680V-9.SPIE.

Lee, S. (2007). *The study on the learner's response in the class using the visual imagery incitement as instructional strategy.* Unpublished master's thesis. Seoul National University. Seoul, Korea.

Lee, J. (2012). *Development of a visual summarizer design model for digital learning.* Unpublished doctoral dissertation. Seoul National University. Seoul, Korea.

Lumpe, A. T., & Butler, K. (2002).The information seeking strategies of high school science students. *Research in Science Education, 32*(4), 549-566.

Mayer, R. E. (2001). *Multimedia Learning.* New York, NY: Cambridge University Press.

Mayer, R. E., & Anderson, R. B. (1991). Animations need narrations: An experimental test of a dual-coding hypothesis. *Journal of Educational Psychology, 83*(4), 484.

Mayer, R. E., & Anderson, R. B. (1992). The instructive animation: Helping students build connections between words and pictures in multimedia learning. *Journal of Educational Psychology, 84*(4), 444.

Mayer, R. E., Bove, w., Bryman, A., Mars, R., &Tapangco, L. (1996). When less is more: Meaningful Learning from visual and verbal summaries of science textbook lessons. *Journal of Educational Psychology, 88*, 64-73.

Mayer, R. E., Mautone, P., & Prothero, W. (2002). Pictorial aids for learning by doing in a multimedia geology simulation game. *Journal of Educational Psychology*, *94*(1), 171.

Merrill, M. D. (1983). Component display theory. *Instructional-design theories and models: An overview of their current status*, *1*, 282-333.

Miller, L. W. (1987). Visual literacy across the curriculum. *Braden, RA, DG Beauchamp,* & *LW Miller (Eds.)*, 105-112.

Norman, D. A. (1988). *The Design of Everyday Things*. New York, NY: Basic Books.

Okebukola, P. A. (1992). Concept mapping with a cooperative learning flavor. *The*

American Biology Teacher, 54(4), 218-221.

Paivio, A. (1971). *Imagery and Verbal Processes.* New York, NY: Psychology Press.

Paivio, A. (1986). *Mental Representations: A dual coding approach.* New York, NY: Oxford University Press.

Park, S., Rha, I., Byun, H., & Kim, T. (2010). The effect of visual scaffolding and visualization tendency on web-based problem solving. Proceedings of Association for the Advancement of Computing in Education(AACE). Penang, Malaysia. May 19-22, 2010.

Pea, R. D. (2004). The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human and activity. *The Journal of Learning Science, 13*(3), 423-451.

Pearson, P. D. & Fielding, L. (1991). Comprehension instruction. In R. Barr, J. L. Kamil, P. Mosenthal, & P. D. Pearson (Eds.), *Handbook of reading research,* Vol. 11(pp.815-860). New York: Longman.

Quintana, C., Krajcik, J., & Soloway, E. (2002). *Scaffolding design guidelines for learner-centered software environments.* Paper presented at the annual meeting of the American Educational Research Association(AERA), New Orleans, LA.

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., Kyza, E. Edelson, D., & Soloway, E. (2004). A scaffolding design framework for software to support science inquiry. *The Journal of the Learning Sciences, 13*(3), 337-386.

Rha, I. (2007). Human visual intelligence and the new territory of educational technology research. *Educational Technology International 8*(1), 1-16.

Rha, I., & Park, S. (2010). The effect of visual and verbal scaffolds on web-based problem solving performance. *Educational Technology International, 11*(2), 97-114.

Rogoff, B. (1990). *Apprenticeship in Thinking: Cognitive Development in Social Context.* NY: Oxford University Press.

Scardamalia, M., & Bereiter, C. (1983). The development of evaluative, diagnostic, and remedial capabilities in children's composing. In M. Martlew (Ed.), *The* *psychology of written language: Developmental and educational perspectives* (pp. 67-95). London: Wiley.

Scardamalia, M., & Bereiter, C. (1985). Research on written composition.In M. C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 778-803). NY: Macmillan.

Schmidt, R., Isenberg, T., Jepp, P., Singh, K., &Wyvill, B. (2007). Sketching, Scaffolding, and Inking: A visual history for interactive 3D modeling. *Proceedings of NPAR*, 23-32, New York, ACM.

Schwartz, D., & Heiser, J. (2005). Spatial Representation and Imagery in Learning. In R. K. Sawyer(Ed.), *The Cambridge Handbook of the Learning Sciences.*(283-298). Cambridge University Press.

Sharma, P. & Hannafin, M. J. (2007). Scaffolding in technology-enhanced learning environments. *Interactive learning environments 15*(1), 27-46.

Sung (2009). *Development and validation of the principles on visual representation of digital text structure for e-learning content.* Unpublished doctoral dissertation. Seoul National University, Seoul, Korea.

Tabak, I. (2004). A complement to emerging patterns of distributed scaffolding. *The Journal of the Learning Sciences, 13*(3), 305-335.

Vygotsky, L. S. (1962). *Thought and language.* Cambridge, MA: MIT Press.

Vygotsky, L. (1978). *Mind in society.* Cambridge, MA: Harvard University Press.

Whitmeyer, S., Feely, M., De Paor, D., Hennessy, R., Whitmeyer, S., Nicoletti, J., ... & Rivera, M. (2009). Visualization techniques in field geology education: A case study from western Ireland. *Geological Society of America Special Papers*, *461*, 105-115.

Wileman, R. E. (1980). *Exercises in visual thinking.* Hastings House Book Publishers.

Wileman, R. E. (1993). *Visual communicating.* Englewood Cliffs, NJ: Educational Technology Publications.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry*, 17, 89-100.

Wood, D., & Middleton, R. (1975). A study of assisted problem solving. *British Journal of Psychology, 66*(2), 181-191.

Yehezkel, C., Ben-Ari, M., & Dreyfus, T. (2007). The contribution of visualization to learning computer architecture. *Computer Science Education, 17*(2), 117-127.

Zeleznik, R. C., Herndon, K. P., & Hughes, J. F. (2007). SKETCH: An interface for sketching 3D scenes. In *ACM SIGGRAPH 2007 courses* (p. 19). ACM.

Zembal-Saul, C., Munford, D., Crawford, B., Friedrichsen, P., & Land, S. (2002). Scaffolding preservice science teachers' evidence-based arguments during an investigation of natural selection. *Research in Science Education, 32*(4), 437-463.

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