Educational Technology International
2010, Vol. 11, No. 2, 1-24

The Effect of Visual and Verbal Scaffoldings on Web-Based Problem Solving Performance

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The study aimed to investigate the differential effects of visual and verbal scaffoldings on web-based problem solving performance. A quasi-experiment with 143 high school students in South Korea was administered. Each student's visualization tendency score was obtained at the beginning of the study. Based on the visualization tendency scores, students were divided into two groups; low and high level visualization tendency groups. Then each group was split in half and randomly assigned to one of the two lessons – one with visual scaffolding and the other with verbal scaffolding. The contents of the two lessons were the same. All students' performance was measured through an essay assignment for a problem solving at the end of the lesson. The result showed that the visual scaffolding group outperformed the verbal scaffolding group (F=22.54, p<.01), regardless of each student's visualization tendency level. The effect size was 0.81, indicating high practical significance. There was no statistically significant interaction effect between scaffolding modalities and students' visualization tendency levels. These findings imply that visual scaffolding is an effective strategy to promote students' problem solving performance.

Keywords : problem solving, visual scaffolding, visualization, visualization tendency

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Introduction

Scaffolding is often used as a strategy to facilitate students' learning and support learners especially in problem-based learning situations (Jonassen, 2010; Wang, 2001). In many cases scaffolding has been offered in verbal format, even though the word, 'scaffolding' originally represents the visually identifiable object and is known to take any form of modality.

Previous studies on the learning activities using visuals mainly examined 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. Numerous studies report that visual activities and materials enhance learners' academic achievement by promoting learners' memorization, understanding, and thinking skills (Park, Rha, Byun, & Kim, 2010). These studies reveal that visual presentation of contents and learners' visual activities are more effective than text-only presentation or verbal activities in content abstraction, understanding, organization, and after all, learning (Kashihara & Sttake, 1988; Piburn, Reynolds, Mcauliffe, Leedy, Birk, & Johnson, 2005; Yehezkel, Ben-Ari, & Dreyfus; 2007). In addition, research on the effectiveness of visual representation such as flow charts, meaning maps, diagrams in problem solving has demonstrated potentials of visuals (Johnson & Satchwell, 1993; Pankratius & Keith 1987; Satchwell, 1997; Stice & Alvarez, 1986). Furthermore, today's advanced web technology makes more diverse and dynamic representation of learning contents in visual format possible. The students are more exposed to visual environment than any other times in human history. Utilization of 'any' materials in visual format would not be unthinkable including the learning and instructional mediators such as scaffolding.

Visual scaffolding, in its lexical sense, would be a type of scaffolding provided in a visual format. It originates from the concept of visualization. Visual scaffolding is a form of conceptualized artifacts in a visual format. It has been argued that one of the fundamental mechanisms of visualization is the formation of the visual representations not only from concrete visual objects but also from abstract meanings (Rha, 2007; Rha, Choi, & Choi, 2009).

Visual scaffolding can take a form of visual objects such as a diagram, a picture, or a 3D visual with or without words. Cuevas, Fiore, and Oser(2002) have studied the effect of visual aids as scaffolding for cognitive and meta cognitive processes. They have used diagrams as visual scaffolds. They found that diagrams facilitated the development of accurate mental models and significantly improved the instructional efficiency because the diagrams functioned as scaffolds. Kidwai, Munyofu, Swain, Ausman, Lin, and Dwyer(2004) reported that they have used the high and low level visual scaffolding for higher order learning. However, there were no significant contributions on learning from the visual scaffolds. They described the visual scaffolding at the conceptual level: simple scaffolding instigates lower levels of cognitive processing in learners as compared to complex scaffolding which instigates higher levels of cognitive processing in the learners (Kidwai et.al., 2004). The study did use the visual scaffolds. But they did not report the process of designing the visual scaffolds.

On the other hand, the relationships between learners' visual characteristics and learning outcome, and the relationships between learners' visual characteristics and instructional support in visual format has not been firmly established. Contrary to our common sense, it is unclear whether a simple statement such as "Some are better at processing words while others are better at processing pictures" is valid. It is also vague whether visual learners have a higher level of visual ability and whether learners with visual preference utilize visual materials more effectively. Well-known studies on learners' visual characteristics are Kozhevnikov, Hegarty, and Mayer(2002)'s and Mayer and Massa(2004)'s research on visualizer-verbalizer in terms of learning preference, cognitive ability and cognitive style. These researchers argue that it is effective to provide visual materials for visualizers, and verbal materials for verbalizers. However, the assumption was not supported in their research (Mayer & Massa, 2004). In another research, visualizers did not show higher spatial abilities compared to the verbalizers (Kozhevnikov et al., 2002). It implies that learners with visual preference might not always have a higher level of visual ability compared with those with verbal preference. The conceptual artifacts such as aptitude, ability, cognitive style, and learner preference appear to be interrelated. There are areas yet to be explored.

Recently, Rha et al.(2009) have developed a measuring tool named 'Visualization Tendency Test' which measures peoples' inclination toward the utilization of the visualization in their everyday life. Based on various visual experiences in ordinary peoples' daily life and exceptionally well known visualization experiences of the historical figures, Rha et al.(2009) have extracted five distinct factors composing human visual intelligence: generative visualization, space-motor visualization, instrumental visualization, proactive visualization, and representational visualization (Rha et al., 2009). Unlike the visualizer-verbalizer measure (Kozhevnikov et al., 2002; Mayer & Massa, 2004), the visualization tendency test measures learners' degree of inclination toward visualization. Interestingly, Rha et al.(2009) reported that the visualization tendency scores of multiple people form a normal curve. This measure might be an appropriate tool for exploring the relationships between visual activities and learning.

In a problem solving situation, learners will try to utilize their full intellectual resources for solving the given problem. The intellectual resources would consist not only of a logic of semantic nature but also of a capability of visual nature. In other words, during the problem solving process, learners will utilize either semantic or visual abilities or both in any given moment. It will be likely to assume that the learner uses semantic or visual abilities according to their natural tendency. Someone with high visualization tendency will use resources of visual nature more frequently (and probably more effectively) comparing to someone with low visualization tendency. Thus when scaffolding is provided in a visual format, it would be reasonable to say that the learners with high visualization tendency will take more advantages of the scaffolding. However, when the scaffolding is provided in a verbal format, the effect will be similar because the verbal scaffolding did not trigger the visual tendency for both learners with high visual tendency and those with low visual tendency.

The purpose of this study is to examine the effects of visual and verbal scaffoldings and visualization tendency on web-based problem solving performance. Research questions are as follows:

1. Is there any significant difference between learners provided with visual scaffolding and those provided with verbal scaffolding in web-based problem solving performance?
2. Is there any significant difference between learners with high and low visualization tendency levels in web-based problem solving performance?
3. Is there any significant interaction effect between different modalities of scaffoldings and visualization tendency levels on problem solving performance?

Research Method

Participants

The participants of this study were 143 high school 11th graders, including 68 male students and 75 female students. The participants were from two high schools located in Seoul, Korea. The reasons we chose this group were: 1) high school 11th graders are considered to have enough ability to have self-control over web-based problem solving, 2) they have appropriate prior knowledge for learning rational social science decision making.

Materials

Materials used in this study were pretest, visualization tendency test, two versions of web-based problem solving programs – a visual scaffolding version and a verbal scaffolding version, and post test.

Pretest

10 pretest items were developed to measure students' prior knowledge level and readiness for studying web-based problem solving program of 'rational decision making'. The test items mainly included social studies contents for 9th graders and 10th graders. Test items were developed and revised by the researchers and two high school social studies teachers. And then, final test items were validated by three high school social studies teachers.

Visualization tendency test

Rha et al.(2009)'s visualization tendency test (See Appendix 1) was modified to be appropriate for high school students. The visualization tendency test consists of 20 self-report items using Likert's 5 scale and its internal consistency, Cronbach α, was .94. Our modified version was validated by 5 educational technology specialists. Through pilot test with 10 high school students, we re-modified the test items and completed final test items. Internal consistency measured by Cronbach α was .86.

Web-based problem solving program with two types of scaffolding

Two versions of web-based problem solving program were developed for the study: a visual scaffolding version and a verbal scaffolding version (See Appendix 2). The program was modified by pilot test with 10 high school students and validated by 5 educational technology specialists, 2 high school social studies teachers.

Designing visual scaffolding

Visual scaffolding was operationally defined as "instructional support which provides learners with structural and sequential information using metaphoric visual shape." Design principles for visual scaffolding were extracted from preceding research on designing visual materials. Furthermore, the principles on designing visual materials were modified for the design of visual scaffolding because there were virtually no design principles specifically for the design of visual scaffolding. Table 1 shows the design principles and strategies of visual scaffolding we deduced from literature reviews.

Table 1. Design Principles and Strategies of Visual Scaffolding

Functions	Design principles	Design strategies	References
Learning goal	Support clear goal perception and task engrossment by utilizing visual tool	-providing visual tool which guide learning trajectory -providing visual tool which promotes task engrossment	Ha(2006) McKenzie(1999)
Learning stage	Support instant grasp of learning structure and process by utilizing visual tool	-providing visual tool which guide problem solving structure -providing visual tool which guide problem solving process	Ha(2006) Hannafin et al.(2001) McKenzie(1999) Quintana et al.(2001)
Learning strategy	Catalyze meta-cognitive thinking and strategic problem solving by utilizing visual tool	-providing visual clue which implies learning strategies -providing visual clue about what learners need to be aware of	Ha(2006) Hannafin et al.(2001) McKenzie(1999)
Emotional support	Preventing anxiety by utilizing visual tool	-providing visual tool which implies hints about next stage	Ha(2006) McKenzie(1999)

Verbal scaffolding was also operationally defined as "instructional support which provides learners with structural information, using verbal guidance." Verbal scaffolding was developed in likely manner to the visual scaffolding mentioned above. The researchers meticulously checked the two scaffolds to keep the same amount of information.

Table 2 shows the resulting design elements of the visual and verbal scaffolds. The researchers decided that visual scaffolding, in this particular problem solving case, has to satisfy following properties: 1) visual scaffolding guides direction or trajectory of problem solving, 2) visual scaffolding guides the process of problem solving in a visually noticeable manner, 3) in terms of learning strategy, visual scaffolding supports learners' problem solving by providing them with tips or hints in visually represented manner for each problem solving process, 4) in emotional aspect, visual scaffolding decreases learners' anxiety by suggesting visual cues on the next step. The final design of the visual scaffold turned out to be 'a face of a man' in its visual look (See Figure1).

Table 2. Design Elements of Visual and Verbal Scaffoldings used in the Study

Functions	Visual Scaffolding	Verbal Scaffolding
Learning Goal	Guide direction of problem solving by comparing the problem solving task as a person's face	Guide direction of problem solving by verbally providing the overall problem solving task structure
Learning Process	Support learners by likening each problem solving process to a process of drawing a person's face from the top to the bottom in orderly manner	Support learners by likening each problem solving process to a process of filling in rectangular box step by step
Learning Strategy	Support learners by providing them with tips or hints visually	Support learners by providing them with tips or hints verbally
Emotional Support	Decrease learner anxiety by suggesting visual cues about what activities learners face next	Decrease learner anxiety by suggesting verbal cues about what activities learners face next

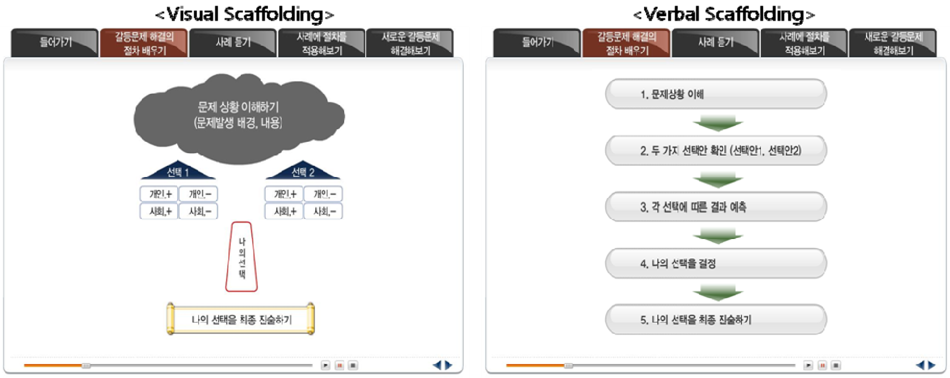

Figure 1. Design of Visual and Verbal Scaffoldings

(English translation is available in Appendix 2)

Post-test

An essay type problem on the ethical judgment was provided as posttest. Students were expected to solve the problem in a logical manner. They wrote about their own solution to the given problem in an essay format. Furthermore, they wrote a supplementary essay on the reflection of their problem solving process. Their essays were graded by criteria developed by two high school social studies teachers and the researchers. Both students' logic of the problem solving process and their solution, and students' descriptions on their problem solving process were graded.

The experimental design and data collection procedure

Experimental design

The experiment was Completely Randomized Factorial design with two factors across the two variables (CRF 2.2). Independent variables are different modalities of scaffoldings - visual scaffolding and verbal scaffolding – as intervention, and students' visualization tendency level. Subsequently, students were categorized into four groups as can be seen in Table 3.

Table 3. Experiment Groups

	Upper 50% of Visualization Tendency	Lower 50% of Visualization Tendency
Visual Scaffolding	G1	G2
Verbal Scaffolding	G3	G4

Data collection procedure

143 students were assigned to the pretest and the visualization tendency test. It took about 20 minutes for both of the test. The pretest was used to verify students' homogeneity in terms of their prior knowledge. One week later, students were randomly divided into two groups and each group studied about 'problem solving with rational decision making process' individually through web-based problem solving program in one-to-one computer assisted instruction environment during their social studies class. Each group studied through web-based problem solving program with visual scaffolding and verbal scaffolding respectively. After this individual learning about rational decision making in computer lab for 50 minutes, each student was assigned to individual problem solving task – writing an essay about one's problem solving process and solution to the problem - for 10 minutes as a post test. Contents of the task were related to what they had learned through web-based problem solving program (See Table 4).

Table 4. Experimental Design

Group	Pretest	Visualization Tendency Test	Treatment	Post test
G1	O1	O2	X1	O3
G2	O1	O2	X1	O3
G3	O1	O2	X2	O3
G4	O1	O2	X2	O3

O1: Pretest

O2: Visualization Tendency Test

X1: Web-Based Problems Solving Program of Visual Scaffolding Version

X2: Web-Based Problems Solving Program of Verbal Scaffolding Version

O3: Post test

Pretest, visualization tendency test, post test were scored, and data from 139 students - 66 male students and 73 female students - were used for the analysis. Four students were dropped during the process of the data collection. The data were analyzed by two-way ANOVA to analyze comparative effects of visual and verbal scaffoldings across visualization tendency.

Results

Descriptive statistics

Table 5 provides descriptive statistics. Mean(*M*) and standard deviation(*SD*) of the web-based problem solving performance scores among students supported by visual scaffolding are 74.14, 9.89 in sequence. Mean and standard deviation of the scores among students provided with verbal scaffolding are 66.30, 9.45 respectively.

In terms of learners' visualization tendency, mean and standard deviation of scores among students with upper 50% level of visualization tendency are 70.21, 10.83 in sequence. Mean and standard deviation of scores among students with lower 50% level of visualization tendency are 70.29, 10.03 each.

Table 5. Descriptive Statistics on Web-Based Problem Solving Performance

		Upper 50% of Visualization Tendency	Lower 50% of Visualization Tendency	Total
Visual Scaffolding	M	74.21	74.06	74.14
	SD	11.12	8.37	9.89
	Cases	38	32	70
Verbal Scaffolding	M	65.61	66.94	66.30
	SD	8.54	10.30	9.45
	Cases	33	36	69
Total	M	70.21	70.29	70.25
	SD	10.83	10.03	10.41
	Cases	71	68	139

Visualization tendency test result

Figure 2 illustrates frequencies of learners' visualization tendency test scores. Mean, median, and mode of the 139 participants' visualization tendency test score were 72.24, 73, and 72 in sequence. Upper 50% of visual tendency group's average score in visual tendency test was 80.63 (*SD*=5.75) while the lower 50% group was 63.49 (*SD*=7.30).

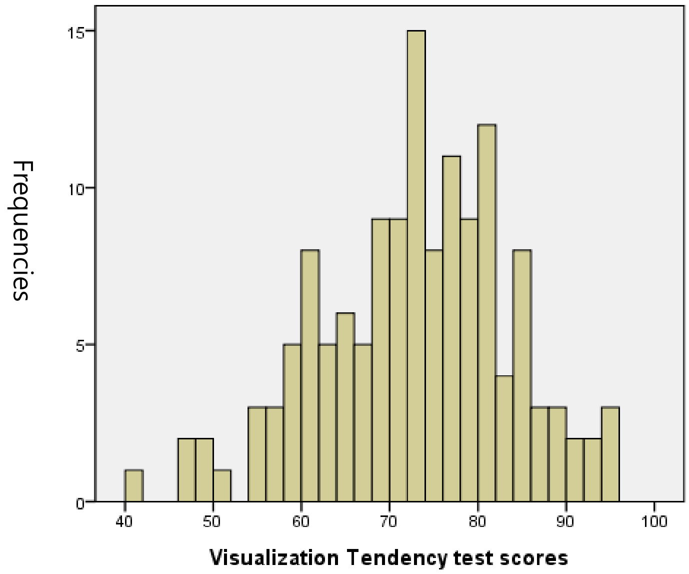

Figure 2. Histogram of Visualization Tendency

The comparative effects of the visual and the verbal scaffoldings across the visualization tendency

Two-way ANOVA was used to verify how scaffolding in different modalities and learners' visualization tendency affect students' performance on web-based problem solving. The ANOVA results about the effect of visual and verbal scaffoldings on web-based problem solving performance, the effect of visualization tendency on web-based problem solving performance, and the interaction effect between different modalities of scaffoldings and visualization tendency are shown in Table 6.

The effect of visual and verbal scaffoldings on web-based problem solving performance

The result of analysis regarding the effect of different scaffolding modalities on web-based problem solving performance is that students provided with visual scaffolding show higher performance in their post test (M=74.14) than those provided with verbal scaffolding (M=66.30). It is statistically significant that scaffolding modalities affect students' web-based problem solving performance (F=22.54, p<.01). The effect size is .81, indicating high practical significance, according to Cohen(1988)'s effect size criteria.

The effect of visualization tendency on web-based problem solving performance

According to the analysis of the relationship between visualization tendency and performance on web-based problem solving (F=.12, p>.01), learners' visualization tendency level does not affect web-based problem solving performance. Learners with upper 50% visualization tendency and those with lower 50% visualization tendency demonstrates no statistically significant difference in terms of web-based problem solving performance.

Different modalities of scaffolding and visualization tendency

The interaction effect between scaffolding modalities and visualization tendency on web-based problem solving performance shows statistically insignificant result (F=.20, p>.01).

Table 6. ANOVA Result on Web-Based Problem Solving Performance

	df	SS	MS	F
Scaffolding Modalities	1	2137.52	2137.52	22.54**
Visualization Tendency	1	12.25	12.25	.12
Scaffolding Modalities × Visualization Tendency	1	19.10	19.10	.20
Residual	135	12799.95	94.81	
Total	139	700975.00		

** $p < .01$

Discussion

Visual scaffolding and web-based problem solving performance

The results of this study show that visual scaffolding has a superior effect on students' performance in a web-based problem solving situation compared with verbal scaffolding. This result counters a study conducted by Kidwai et.al.(2004) reporting no significant effect of visual scaffolding on final scores. Although Cuevas et al.(2002) did discover some advantages of using diagram as a visual scaffolding in their study, their interests were cognitive and meta-cognitive facilitation functions of the visual scaffolding. In this study, the visual scaffolding was intentionally designed to compare its effect with that of the verbal scaffolding.

There might be two reasons for the superiority of visual scaffolding over verbal scaffolding. First, visual scaffold naturally provides more information for learners. Visuals cannot help providing some additional information while displaying the visual image itself. For example, shape, space, direction, structure, relationship, size and color are all supplementary information naturally included in the visual image of visual scaffolding. Though not written in verbal terms, pieces of information are scattered in the shape and the space of visual scaffolds, therefore providing richer information to learners. Students might have taken advantages of this additional information from visual scaffolds for their problem solving, let alone the memorization of the information. In contrast, verbal scaffolding group students are exposed only to the certain verbal information.

Second, visual scaffold might have led learners to understand overall problem solving tasks more comprehensively with less cognitive load. This is mainly because visual scaffolding provides students with spatial representation about the problem solving structure or process. Schwartz and Heiser(2005) substantiated that learners understand particular knowledge structure effortlessly if they are provided with spatial representation about the content structures. This external representation may facilitate learners to form internal representation about certain problem solving task (Jonassen & Hung, 2006). Additionally, learners might experience more insightful perspectives, more in-depth understanding, and higher order thinking and problem solving skills (Buzan, 1994; Okebukola, 1992; Quintana et al., 2001).

Visualization tendency and web-based problem solving performance

Students' visualization tendency level has no significant impact on their web-based problem solving performance. It may be that the visualization tendency is independent from visual ability or spatial ability. It seems that visualization tendency is not the visual ability itself but rather the preference of utilizing the visual ability, which could be supported by Kozhevnikov et al.(2002)'s study that there are two type of visualizers; one with a high spatial ability, and the other with a low spatial ability. Another possibility is that the low visual tendency learners had more advantages than the higher tendency learners and thus, as a result, the effects were similar. The visual scaffoldings might have helped more someone with less visualization tendency than someone with higher visualization tendency. Because the learner with lower visualization tendency is less likely to come up with a visualization of the original semantic materials compared to the person with higher visualization tendency. The visual scaffolding, if seen from the learner with less visualization tendency, provides 'readymade' extra visual information easier to take in and process. As a result, the learners with the less visualization tendency took more advantages of the visual scaffold.

A great number of studies emphasized positive effect of visual activity or ability on learning outcome. Visual activity catalyzes intuitive, comprehensive, and creative thinking (Root-Bernstein & Root-Bernstein, 1999; Williams, 1983). It also contributes to more effective learning by encouraging students to grasp overall learning process, and facilitating understanding and remembering contents (Bransford & Johnson, 1972; Kashihara & Sttake, 1988; Piburn et al., 2005). In this manner, the natural tendency toward visualization has possibility of yielding positive results on learning and higher order thinking skills such as problem solving and creativity. Obviously, there needs to be more research to demonstrate the complex relationships among visualization tendency, visual ability, learning, and higher order thinking

Design of visual scaffolding

Visual scaffolding can take any form of visual objects. In this study, visual scaffold was the words arranged in boxes and triangles and the total shape of the information was arranged in a way for learners to remind a person's face. The general principles of designing visual scaffolding are yet to be explored. The experience of the researchers in this study suggests following three stages as a starting point. First, decide learning contents someone wishes to scaffold. It can be ideas, processes, sentences, or shapes. Second, apply the temporary principles of visual scaffolds suggested by the previous research, such as the principles of learning goal, learning process, learning strategy, and emotional support. Finally, come up with a shape integrating the whole idea. The shape can be with or without text, 2D or 3D. It would be ideal if the shape of visual scaffolds matches with the mental model of learners. Again, it is obvious that there needs to be more research on designing visual scaffolds.

Conclusion

This study focused on the differential effect of visual and verbal scaffoldings across learners' visualization tendency level on web-based problem solving performance. Visual scaffolding showed statistically meaningful differences in performance scores over verbal scaffolding. On the contrary, visualization tendency demonstrated no statistically significant effect. The interaction effect between scaffolding modalities and visualization tendency was statistically insignificant.

The results of the study bring about a series of new questions. Where does the effectiveness of visual scaffold come from? Is it from the design or the content? How does the visual scaffold support learners? Is it by helping students' memory or by lessening their cognitive load? When we design a visual scaffold, should it be a completed shape or should be left incomplete so that the learners can fill-in the missing areas?

This research demonstrated the potentials of visuals and suggested that more scaffoldings in visual format are to be considered in teaching-learning design to enhance learning outcomes. Starting from the prototypical visual scaffolding developed in this research, better solutions on designing visual scaffoldings have to be studied. In this visual media-driven society where visuals, especially digital visuals are used extensively to communication, educators should seriously consider using materials in visual format as a mediator of learning and instruction.

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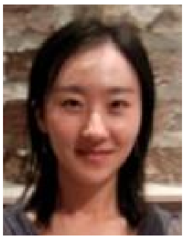

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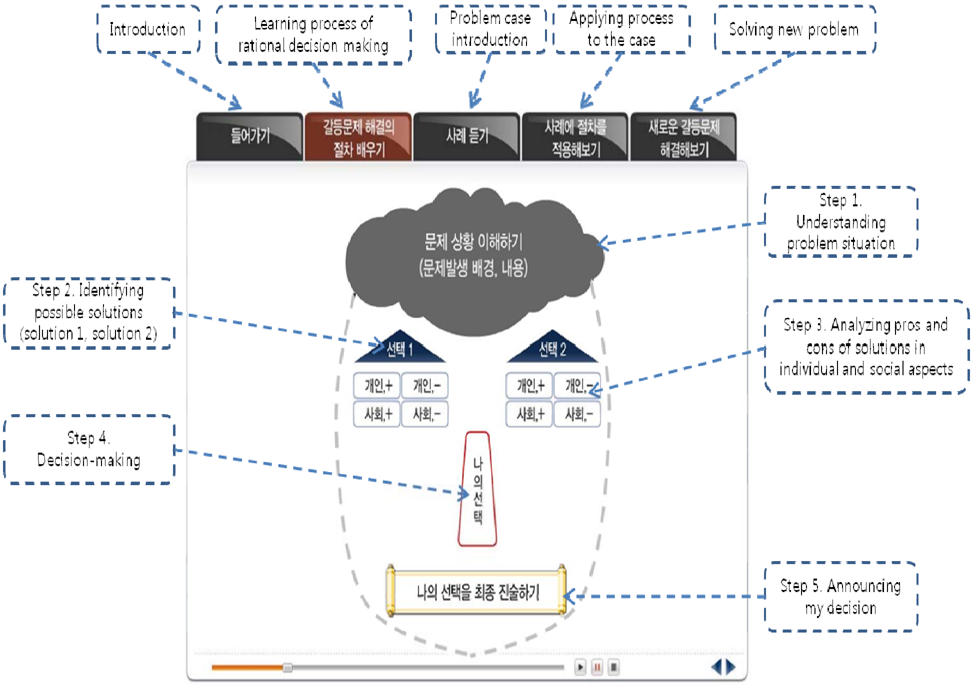
Received 2010.09.28./ Peer Review Completed 10.21./ Accepted 10.26

Appendix 1. Visualization Tendency Test (Rha et al., 2009)

Factors	Number of Items	Items
Generative Visualization	5	- I tend to infer related or influencing factors when I see things. - I am good at inventing or devising necessary or gadgetry things by using imaginative-reasoning. - When touching or reaching a certain item with a hand, I tend to figure the things in images. - I tend to associate things with other things that look similar. - When looking at objects, I tend to fill the unseen or missing parts of them figuring out the whole look.
Space-Motor Visualization	4	- When throwing an object, I can easily guess where the object will reach when. - I can envision my movement in the axis of coordinates. - While parking a car, I tend to picture the parking motion of the car. - When playing some sports such as golf, football, and swimming, I imagine my body movement in my head like "image training".
Instrumental Visualization	4	- When I would explain a complicated story or a person's delicate characters, I can describe them by pictures. - I tend to take notes by using visual languages such as symbols, marks, diagrams or pictures. - When taking a note or learning some contents, I tend to reorganize them in a figure, a picture or table. - In attempting to figure out complicated matter, I tend to draw diagrams or pictures.
Proactive Visualization	4	- When spending some free time, I tend to frame and visualize something to myself. - I usually imagine my future with clear picture or images - I tend to enjoy visualizing and imaging things and matters. - When choosing some clothes, without trying on myself I try to figure it out if they go well with me.
Representatio nal Visualization	3	- While listening to music or lyrics of a song, I usually hit upon related scenes or images of the music or song. - While reading a book, I tend to picture scenes to myself. - While listening to a story, I tend to let my imagination run.
Total	20	

Appendix 2. Web-based Problem Solving Programs with Different Modalities of Scaffolding

1) Visual Scaffolding Version



2) Verbal Scaffolding Version