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Study on Effective Visual Resources According to Their Role in Teaching-Learning Activity - In the "Regularity in Chemical Reactions" Unit in the Ninth Grade Science Textbook

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ABSTRACT. This study explores the effective visual resources in the "regularity in chemical reactions" unit of ninth grade science textbooks (2009 revised version). The frequency and role of visual resources were initially examined, and the students' perceptions of visual resources were investigated. The results of the analysis represented the learning material presentation (68%), motivational categories (14%), guide to inquiry procedures (9%), and inquiry results and summaries (8%). According to the investigation of the students' perceptions of visual resources, the most effective visual resource for motivation is a photograph depicting physical and chemical changes, such as in bread baking and the most effective for learning material presentations in mass conservation, definite proportion, and stoichiometric concept units were a cartoon, graph, and formula representing stoichiometric phenomena, respectively. The most effective resource for guide to inquiry (experimental) procedures were photographs of both instruments and sequential experiment processes; and in the inquiry results and summary category, incomplete tables and graphs for students to work on themselves. The aims of this research are to increase the usefulness of visual resources in the teaching-learning activity and provide informative supplements for the development and improvement of visual resources, according to the students' perceptions.

Key words: Visual resource, Motivational materials, Learning material presentation, Guide to inquiry procedure, Inquiry results and summary

INTRODUCTION

Curriculums represent the educational direction of each era, reflecting the characteristics of the society and the concept of talent. Based on the seventh national curriculum, the revised 2009 curriculum aims to fit students with a high level of creativity and humanity - required by a futuristic and technologically advanced society - and to nurture people of talent. The contents stipulated by curriculums are reflected in textbooks. Textbooks are the most important learning material[1] and include not only the learning content but also inquiry activities, teaching and learning methods, etc. Textbooks are composed of textual (explaining the contents of the book in writing) and visual parts (explaining the contents of the book schematically using visual resources).[2] Visual resources effectively show the textbook contents and induce students' curiosity by being striking. Moreover, they not only help centralize attention, but also constitute a very effective tool in developing curiosity, imagination, creativity, and character.[3-5] Particularly, visual materials are effective for explaining specific concepts concretely and implicitly.[6,7] Visual resources not only include scientific facticity, clarity, and curiosity but also are motivational, informational, provide inquiry methods, results and summaries, and help understand the textbook contents.[8]

Textual explanations of scientific concepts are significantly limited; a visual explanation is required to overcome such limitations. In such cases, it is important to use visual resources that fit the learners' cognitive level. Visual resources are less effective when they either exceed or fall short of the learners' cognitive level. Selecting and allocating the appropriate visual resources in accordance with the textbook contents is as important as utilizing the right teaching and learning methods.[9] This implies giving consideration to the characteristics of the textbook contents and the cognitive characteristics of learners to select the appropriate form, level, and arrangement of the different visual resources. Furthermore, factors such as the diversification, concretization, visualization, and design of visual resource representation are also important to increase learning interest. Textbook liberalization was revealed to significantly increase interest in visual resources, and a lot of research has been conducted on this topic (such as quantitative comparative research on visual resources,[8,10–16] and recognition survey research on the understanding of visual resources[15,17–19]). However, relatively little research is being conducted on the visual resources of the revised 2009 curriculum science textbook chemistry units.

So far, visual resource research has been conducted on units that range over the phenomena-centered macroscopic world, treating with scientific phenomena and changes.[15,18,19] In addition, effectiveness research performed through recognition surveys has mainly selected units composed by visual resources that can be easily encountered in one's daily life.[15,18,19] However, the object of this study is a unit called "Regularity in Chemical Reactions," a stoichiometric unit that explains concepts at the molecular and atomic level. The scientific concepts (law of conservation of mass, law of definite proportions, law of gaseous reaction) presented in this unit are not familiar in daily life and include difficult contents that explain stoichiometrically material changes before and after chemical reactions. The results of this stoichiometric study are expected to be different from those reported in previous research.

The object of this study is based on mathematical concepts and at the same time, enlightens learners about particle rearrangement concepts. It explains concepts such as the law of conservation of mass, law of constant composition, and law of gaseous reaction using atomic and molecular models. Since explaining these difficult concepts using only texts and one-time experiments has certain limitations, this unit uses various visual resources such as reaction equations, diagrams, figures, and mixed types (multiples). After performing a survey on the visual resources involved in teaching and learning, the following questions were asked to investigate their effectiveness based on the achievement level.

1) How are the distribution and features of the visual resources involved in teaching and learning?

2) What is the most effective visual resource based on the level of scientific achievement?

RESEARCH METHOD

Subject of study

The visual resources included in the "Regularity in Chemical Reactions" unit of nine ninth grade science textbooks (revised 2009 version) were analyzed. This unit explains concepts regarding the law of conservation of mass, law of definite proportions, and law of gaseous reaction. Unit summaries and conclusions, problems, questions, free research, reading articles, and steam materials were excluded from the analysis because each textbook has a different content composition. To simplify the publishing companies' names, the letters A (Kyohaksa Co., Ltd.), B (Kumsung Publishing Co., Ltd.), C (Mirae-n Co., Ltd.), D (Donga Publishing Co., Ltd.), E (Visang Co., Ltd.), F (Sinsago Co., Ltd.), G (Jihaksa Publishing Co., Ltd.), H (Chunjae Education Inc. (Shin)), and I (Chunjae Education Inc. (Lee)) were used instead.

Research method and judgment standard of items

Based on the previous classifications,[6,16,18,19] the subcategories reaction equations, summaries, tables, and mixed types were added (see *Table* 1). Visual resources were classified into eight subcategories: photos, figures, diagrams,

***Table* 1.** Type of visual resources according to teaching-learning roles

Role	Subcategory of visual material
Motivation	Photos, figures, diagrams, cartoons, tables, graphs, reaction equations, mixed type (multiple)
Learning material presentation	Photographs, figures, diagrams, cartoons, tables, graphs, reaction equations, mixed type (multiple)
Inquiry procedure guidance	Photograph showing one scene of the main experiment devices Photograph showing sequential experiment procedures, including experiment devices Photograph showing one scene of a student performing the main experiment Photograph showing sequential scenes of students performing the experiment Photograph showing sequential experiment procedures, including experiment devices and students Reaction equations showing reactions through models, diagrams, and chemical equations Tables that guide and briefly summarize the experiment procedure
Inquiry results/summary	Presentation to complete only the table, using the given experiment results Presentation to complete only the graph, using the given experiment results Presentation to complete the table and the graph, using the given experiment results Presentation to complete only the table, using the performed experiment results Presentation to complete only the graph, using the performed experiment results Presentation to complete the table and the graph, using the performed experiment results Presentation to complete part or all reaction equations in the given reaction

cartoons, tables, graphs, reaction equations, and mixed types (multiple). In contrast, textbooks presented four kinds of visual resources (photos, tables, graphs, and reaction equations) in the guide to inquiry section and in the inquiry result and summary sections. Photographs were used to reproduce the shape of things. Figures are paintings that represent scientific phenomena or activities fully and realistically. Diagrams are partial and abstract figures of scientific phenomena (scientific models with explanatory situations). Cartoons are drawings that show the characteristics of objects or phenomena in a humorous and exaggerated way, and contain dialogues and speech bubbles. Tables are charts that analyze several variables and show the relation between them. Graphs are figures that analyze several variables and show their relation or changes in an easily recognizable way using lines or curves. Reaction equations allocate reactants to the left of the arrow, and products to the right, uniting them with a + sign. Finally, two or more types of visual resources combined are called "mixed type" or multiple.

The contents of science textbooks include stages such as introduction, content development, results summary, etc. The introduction section includes motivational and familiar visual resources, forming a cognitive bridge that helps learners understand the unit concepts. The content development section presents explanations of the contents as well as inquiry experiments, and explains the inquiry methods and procedure in detail using visual resources. Finally, the results obtained through the inquiry experiments and activities are summarized and visual resources through which the learned concepts can be rechecked are presented. The purpose of the motivation role is to increase learners' attention and interest toward the activity. Learning materials include visual resources that help students understand specific concepts during the learning activity. Inquiry procedure guidance informs students about the inquiry procedure, that is, inquiry contents, order, methods, etc. Inquiry results and summary include visual resources that help students deduct inquiry results and confirm and elaborate what they have learned.

The classification standard of visual resources is as follows. 1) Visual resources having the same background or content, 2) visual resources being presented in order, by stages or time, and 3) visual resources being apart but having the same content, were classified as one. Two visual resources being together with the same background were classified as one; those with different backgrounds were classified separately. Visual resources overlapping were classified as one if, having the same content, they had expanded or changed along with the arrow. Phased visual resources connected by arrows or consecutive visual resources regarding temporal variations of the same object were classified as one. Two researchers primarily classified visual resources of the subject unit. Each researcher classified a visual resource by type and role. Discrepant items were determined after discussing with each researcher from his own perspective. Finally, discrepant items were classified after consulting with a specialist.

Visual resources survey

The visual resources survey was performed on 307 ninth grade students of a middle school located in Jinju, Korea. The survey was called "Survey on the visual resources included in the 'Regularity in Chemical Reactions' unit of ninth grade science textbooks (revised 2009 version)." Students were encouraged to select what they considered the most effective visual resource for each role and explain their selection. The subjects of this survey were ninth grade students who had already studied "Regularity in Chemical Reactions" unit. Although there was no study on the effectiveness of the survey or the optimum time for carrying it out, the purpose of the survey was fully explained to students after eight weeks of learning completion and they were encouraged to participate in it wholeheartedly. After this, 291 students were selected as research subjects (19 respondents were excluded for being undependable). Based on the science grades of the first semester final exams, students were divided into three groups (high, medium, and low), and the most effective visual resources in terms of contents understanding for the three groups were compared and analyzed. The final exam grades of the 291 students were normally distributed. As mentioned before, students were randomly divided by their final exams into three groups: high (97 students with grades above 81.0 out of 100 points), medium (97 students with grades between 81.0 and 59.7), and low (97 students with grades below 59.7). The survey period was from June 29 to July 3, 2015. Surveys were directly distributed and collected right after completion. The survey completion time was 45 minutes.

The survey contained six items. Items regarding motivation were selected from the physical and chemical changes sections; those regarding learning material presentation were selected from the law of conservation of mass, law of definite proportions, and law of gaseous reaction sections; those regarding inquiry procedure guidance were selected from the law of conservation of mass section; and those regarding inquiry results and summary were selected from the law of definite proportions section. In this unit, visual resources considered significantly connected to main concepts were selected first. Visual resources to be included in the survey items were selected by differentiating them by those corresponding to one subcategory, those corresponding to two subcategories, from the simplest to the most complicated, from the most concrete to the most abstract, and from those including the easiest contents to those including the most difficult contents. From visual resources with high frequency, those more related to the explanation of contents were included in the survey items of each role and checked. The researcher of this study personally made the survey, referring to previous studies. The researcher primarily selected the survey items and two specialists determined their validity in accordance with the aforementioned standard.

RESEARCH RESULTS AND DISCUSSION

Visual resources analysis by role

The visual resources of the "Regularity in Chemical Reactions" unit of nine ninth grade science textbooks were analyzed by role. The results were: learning material presentation (68%; 434 objects), motivation (14%; 91 objects), inquiry procedure guidance (9%; 59), and inquiry results and summary (8%; 52 object). The reason learning material presentation had the highest frequency was because it is mainly used as a base for explaining scientific theories or laws and a variety of visual resources are required to make students understand such concepts. Other analyses of the chemistry sections of the revised 2007science textbooks[18,19] and science textbooks corresponding to the seventh curriculum[8,15] also revealed that visual resources from learning material presentation appeared more frequently than others.

The types of visual resources were analyzed to identify the characteristics of the unit contents. The results were 268 photos (42%), 127 reaction equations (20%), 109 mixed type visual resources (17%), 45 diagrams (7%), 35 tables (6%), 29 figures (5%), 16 graphs (2%), and 13 cartoons (2%). The reason photos had the highest frequency was not only because they are the best tool for depicting realistically scientific facts and phenomena that exist in nature but also because they allow students to experience indirectly scientific concepts that are difficult to understand. Furthermore, photos are a good tool in terms of convenience and affordability. Photos also had the highest frequency of use in the chemistry units of the revised 2007 science textbooks[18,19] and science textbooks corresponding to the seventh curriculum.[8,15] The reason reaction equations presented a high frequency of use was because they are the best tool for expressing stoichiometric relations (such as the law of conservation of mass, law of definite proportions, and law of gaseous reaction) before and after the reaction.

Visual resources analysis per role: Motivation

Several visual resources were implemented to motivate students in the introduction section of the "Regularity in Chemical Reactions" unit. Motivational visual resources were analyzed and found to be composed by photos (56%), figures (23%), and cartoons (10%). In comparison with other textbooks analyzed, figures were used relatively more in textbook A, cartoons were used more in textbook E, and mixed type visual resources were used more in textbook G. In previous analyses on the motivational visual resources of textbooks,[18,19,21] photos were found to be most frequently used.

A relatively high number of motivational visual resources were present in the physical and chemical changes section, which is an introduction stage. Examples of changes that can be easily observed in daily life (changes in materials' form and state, sugar dissolution, metal corrosion, objects combustion, fruit or leaf color changes, fireworks, sediment or gas generation, etc.) were cited and simple inquiry experiments (creating models of material changes, observing heating changes in sugar, electrolysis, boiling water, observing changes in the form of metals, carrying out combustion tests, observing the light and heat emitted by burning candles, adding vinegar to eggshells, etc.) were implemented to increase the interest and curiosity of students when learning this concept. Survey questions were asked as shown in Survey #1 after selecting the motivational visual resources. This survey aimed to investigate which visual resources more effectively motivated students to learn. The results selected by students are shown in *Fig.* 1. Students mostly selected option "d" as the most effective visual resource for the following reason.

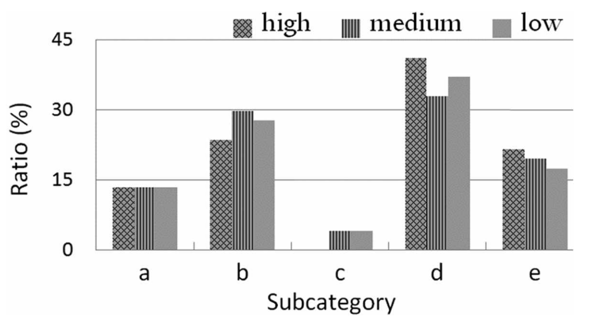

***Figure* 1.** Study of students' awareness of motivation. **a**: Photo of combustion of a candle. **b**: Photo of the sequential process of melting sugar by heating. **c**: Figure of a campfire scene. **d**: Photo of the sequential procedure of bread-baking. **e**: Cartoon of a kitchen scene in which breakfast is prepared.

*Student A (**High**): "The photos show the bread-baking process clearly and by stages, separating physical from chemical changes, which makes it easier to understand."*

*Student B (**Middle**): "The photos show clearly how the bread expands while being baked and how its color changes gradually, which make the contents understandable."*

*Student C (**Low**): "I know well how to bake breads because I have done it from an early age; these photos make the contents easier to understand because it is something I am familiar with."*

Familiar materials, experience of the contents, and concrete and visual expressions are some characteristics that increased the interest and attention of students toward scientific contents and made them easier to understand. By clearly showing the bread-baking process, the students could understand not only the concept of physical and chemical changes but also the difference between them. Expressing two different concepts within one single process can help students better understand the differences between both concepts. Particularly, students from the **low** group showed a higher degree of interest and attention because the bread-baking process was something they were familiar with and connected to the contents of the learning activity. That is, the learning process becomes easier when facts personally experienced by students (questions **b** and **d**) are connected to scientific contents. Students belonging to the **high** (41.2%), **middle** (33.0%), and **low** (37.1%) selected question **d** at a similar rate. Previous survey results[15,18,19,21] regarding "the states of matter," "molecular motion," and "change of state" revealed that concrete and detailed visual resources including explanatory cartoons or diagrams were more effective to motivate students to learn. This study revealed that photos showing the process of materials previously experienced by students step-by-step are more effective. Regardless of the type of visual resources used, if they are concrete, detailed, and familiar, they will more effectively help students understand the learning concepts.

In accordance with results of an analysis on the cognitive levels,[17] formal operational students look forward to expanding the relation between visual resources and the learning concepts, and concrete operational students want visual resources they are familiar with. In this study, students belonging to the **high** group said that understanding the learning concepts was easier only with phased photos (symbolic representations). However, students belonging to the **low** group said that familiar visual resources (concrete representations) were more effective for them to understand the learning concepts. This suggests that visual resources must be implemented differently according to the cognitive level of students.

Visual resource analysis per role: Learning material presentation

The visual resources corresponding to the learning material presentation role were found in proportions of 42 (photos), 20 (reaction equations), 18 (mixed type), and 11% (diagrams) in the stoichiometric concepts of the "Regularity in Chemical Reactions" unit. The reason photos occupied the largest proportion was because they are more appropriate for representing realistically scientific, natural, and living situations. The proportion of reaction equations was also comparatively high. In contrast, visual resources of learning material presentation were found in the highest proportion in textbook D, and in the lowest proportion in textbook I. The learning activities of the "Regularity in Chemical Reactions" unit are divided into three concepts: law of conservation of mass, law of definite proportions, and law of gaseous reaction. These concepts were surveyed for explanations with several visual resources of learning material presentation.

When teaching and learning the **law of conservation of mass,** questions were asked as shown in Survey #2 by selecting visual resources used as examples (models and photos regarding mass conservation in sediment formation reactions, models regarding mass conservation in gas generating reactions, photos and models regarding mass conservation in combustion reactions, models of mass conservation before and after chemical reactions, etc.) and visual resources used in simple inquiry experiments (inquiry experiments regarding mass conservation in sediment formation reactions, mass conservation in gas generating reactions, and mass conservation in combustion reactions, adding ammonia water to rusty coins, inquiry experiments regarding mass conservation in oxidation reactions, etc.). As shown in *Fig.* 2, the majority selected option **d** as the most effective visual resource for the following reason.

*Student A (**High**): "Cartoons themselves induce students to show more attention and interest, because they are funny and straightforward. Also, they include textual explanations, making it easy to understand."*

*Student B (**Middle**): "Many students enjoy reading cartoons; they are appealing and draw the attention of students."*

*Student C (**Low**): "Cartoons include cute characters, which feel closer and draw one's attention."*

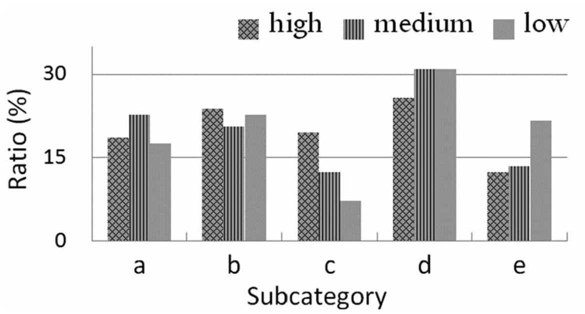

Figure 2. Study of students' awareness of learning material presentation. **a**: Figure of a different arrangement of two kinds of balls on a pair of scales. **b**: Reaction equation representing formation reaction of copper oxide. **c**: Diagram of steel wool combustion in a closed space. **d**: Cartoon of steel wool combustion. **e**: Mixed type showing steel wool combustion in a non-enclosed space.

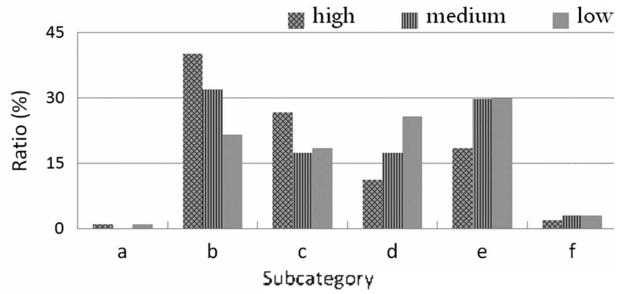

Figure 3. Study of students' awareness of learning material presentation. **a**: Photo of a copper oxide generation experiment. **b**: Graph showing mass ratio of copper oxide (linear). **c**: Graph showing mass ratio of copper oxide (diagram). **d**: Figure of the procedure for making a sandwich using bread and ham. **e**: Figure of the carbon dioxide formation reaction. **f**: Table showing reaction of iron and oxygen.

Option **d** (cartoon) was the most effective for understanding the contents because it included textual explanations. Moreover, students normally like cartoons, which make them feel closer and show less resistance toward the learning contents. Even though other options explained mass conservation concretely and in detail using models, photos, and figures, students selected the cartoon option. Thus, to help students understand stoichiometric concepts, visual resources such as cartoons should be used more.

The **law of definite proportions** states that any given chemical compound will have the same elements in the same proportion or ratio by mass. To help students understand this concept, questions were asked as shown in Survey #3 by selecting visual resources used as examples (graphs regarding the mass ratio of elements in a given chemical compound, photos (models and reaction equations) regarding the mass ratio of component elements in sediment formation reactions, graphs (models, reaction equations, and tables) regarding the mass ratio of component elements in combustion reactions, photos (reaction equations) regarding the mass ratio of component elements using models, and figures regarding the ingredient distribution ratio in sandwiches) and visual resources used in simple inquiry experiments (experiments performed to demonstrate whether rests of magnesium remain after a gas formation reaction, experiments regarding the mass ratio of the component elements of a product in oxidation reactions, and experiments regarding the mass ratio of component elements in producing reactions using molecular models). Students were encouraged to select what they considered the most effective visual resource of learning material presentation; the results are shown in *Fig*. 3. The selected options were different depending on the academic achievement level of students (**high**- and **middle**-group students selected option **b**, and **low**-group students selected option **e**) for the following reason.

Student A (**High**): *"The graph shows simply how the mass ratio of copper and oxygen, the component elements of copper oxide, increases uniformly, making it easier to understand."*

Student B (**Middle**): *"The graph shows that the mass ratio of copper and oxygen increases uniformly, making it easier to understand."*

Student C (**Low**): *"The contents are explained using characters similar to those of cartoons, so it is more interesting and I can focus more easily on learning. It was clear that carbon dioxide is composed of a carbon atom bonded to two oxygen atoms."*

High– and middle-group students selected option b, which explained that the mass ratio of copper and oxygen is always uniform in copper oxide. Low-group students preferred option e, which expressed the mass ratio using cute cartoon-like characters. High-group students showed a preference toward visual resources expressing theories or principles clearly. Contrarily, visual resources expressing contents too simply complicatedly were found to decrease the accessibility of low-group students. Thus, the most effective visual resources were concluded to be those that include concrete explanations and are suited to the student's level, giving consideration to both learning concepts and design. This suggests that concrete visual resources must be presented on every level in accordance with the cognitive level of students.

The **law of gaseous reaction** states that in chemical

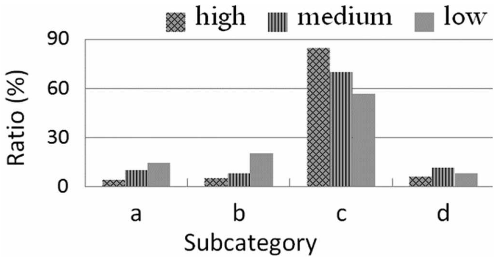

***Figure* 4.** Study of students' awareness of learning material presentation. **a**: Figure of a device generating steam in a hydrogen/oxygen combination reaction. **b**: Table showing the before and after ratio in the formation reaction of ammonia. **c**: Reaction equation representing formation reaction of steam. **d**: Table showing the result of the formation reaction of steam.

reactions, there is a volume ratio between the reactant and the reactant and product combined. This law is explained to students by explaining the proportional relationship of reactants and products using a model of volume ratio or by performing volume measurements in gas generating experiments (water vapor, hydrogen chloride, carbon dioxide, and ammonia). Avogadro's law is used to explain the relationship between gas volume and the number of moles, particularly in textbooks A, D, F, and G. Textbook I explains the law of gaseous reaction through mixed visual resources including cartoons, diagrams, and models. Questions were asked as shown in Survey #4 after selecting the aforementioned visual resources. Students were encouraged to select what they considered the most effective visual resource; the results are shown in *Fig.* 4. Most students selected option **c**, which includes molecular models and volume concepts for the following reason.

*Student A (**High**): "The relationship between a uniform volume ratio and the number of moles was explained as one using a volume model and a molecular model, respectively, and the chemical reaction equation was expressed visually, making it easier to understand."*

*Student B (**Middle**): "The volume ratio of the reactant's hydrogen and oxygen is 2:1, and the volume ratio of the product's vapor is 2. The formation process was expressed straightforward through figures and models, making it easier to understand."*

*Student C (**Low**): "Expressing the chemical reaction equation through molecular models and figures makes it look simpler and easier to understand."*

A relatively high percentage of students (**high** group: 85%; **middle** group: 70%; **low** group: 57%) selected option **c**. Realistic and concrete visual resources expressing the proportional relationship of hydrogen, oxygen, and vapor (2:1:2, respectively) before and after the reaction were found to contribute greatly to learning material presentation. In contrast, although students were presented with several visual resources, some were not selected. In addition, complicated visual resources were found less effective as they made the unit contents more difficult to understand. Analysis results[19] of the unit called "Properties of materials" revealed that photos were used more in learning material presentation, but students preferred the mixed type. Other survey results[15,21] revealed that students preferred cartoons as they organize scientific concepts and make them easier to understand. As seen, textbook analysis results and survey results were different. In textbooks, using visual resources corresponding to the survey results is expected to increase the teaching and learning effectiveness and help students approach difficult scientific contents more easily.

Visual resources analysis per role: Inquiry procedure guidance

Inquiry procedure guidance constitutes a series of processes providing guidance on inquiry methods and procedures, so that inquiry experiments and activities can be successfully performed. The visual resources used in inquiry experiments of science textbooks included: 1) photos showing one scene of the main experiment devices for simple experiments such as heating, 2) scenes and photos by stages if the inquiry procedure required precision, and 3) photos showing each stage of the experimental procedure - including experiment devices, students, and detailed explanations - if the inquiry procedure was sequential or required manual work. The proportions at which these visual resources were used were 26 (photos showing each stage of the experiment procedure, including devices and students), 25 (photos showing each stage of the experiment procedure, including devices), and 22% (photos showing only one scene of the main experiment devices). There was no great difference in the proportion at which these three types of visual resources were used.

Inquiry experiments regarding the concept of mass conservation (sediment forming, gas generating, combustion, and oxidation reactions) were found in a relatively higher proportion. Thus, visual resources of inquiry procedure guidance for this concept were selected. Questions were asked using these visual resources as shown in Survey #5 to investigate which one was most effective. The results are shown in *Fig.* 5. More students selected option b for the following reason.

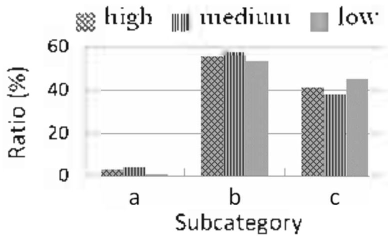

***Figure* 5.** Study of students' awareness for guide to inquiry procedure. **a**: Photograph of a main experiment scene in the gaseous formation reaction. **b**: Photograph of sequential experiment procedures, including devices, in the gaseous generation experiment. **c**: Photograph of sequential experiment procedures, including devices and students, in the gaseous generation experiment.

*Student A (**High**): "It was easy to understand because photos include the experiment devices and the experiment procedure is shown sequentially and concretely (same mass)."*

*Student B (**Middle**): "The experimental procedure is shown by stages and it is clear that gas was generated because the balloon became inflated, which was appealing."*

*Student C (**Low**): "The experimental procedure is shown in a simple way and sequentially. Watching how the balloon changes step-by-step increases attention and concentration."*

Option **b** included photographs showing experiment devices, the sequential procedure of the experiment, and simple explanations. Students who are not familiar with the experiment could not understand the procedure by only reading textual explanations, which is why they said that the experiment was easier to understand after looking at photographs of the experiment procedure. Such photographs not only provide guidance about the inquiry methods but also allow students to know if they have conducted the experiment successfully. A significant number of the students who selected option **b** show great interest toward verifying the mass conservation using scales and by observing the volume changes of the balloon. Thus, option **b** was the most effective visual resource for students. Particularly, as stated by student B (Middle), since the process during which a solid (eggshell) changes into a gas (hydrogen) can generate misconceptions regarding mass changes, the high interest and curiosity of students was probably what made them select this option.

The analysis of science textbooks of the revised 2007 curriculum[18,19] revealed that photographs showing only one scene of the main experiment devices were used more. However, surveyed students said that photographs showing the experiment procedure sequentially, including devices and students, and explanations of each stage of the experiment, were most effective. So far, surveyed students have showed a preference for inquiry procedure guidance visual resources showing the experimental procedure concretely and systematically.

Visual resources analysis per role: Inquiry results and summary

The inquiry results and summary roles have a series of processes in which students analyze and summarize the information acquired during the experiment. In this process, visual resources such as tables, graphs, reaction equations, and textual explanations are presented. The textbook analysis revealed that "table completion using performed experiment results" was the most frequently used, followed by "table and graph completion using performed experiment results." The reason for this was that, when the experiment results are summarized using tables or graphs, concepts such as the law of conservation of mass, law of definite proportions, and law of gaseous reaction can be more easily understood by the noticeable difference before and after the reaction.

Survey #6 was made using visual resources whose purpose is to help students summarize inquiry results in the "law of definite proportions" section. Then, students were encouraged to select what they considered the most effective visual resource. The results are shown in *Fig.* 6. In most of the textbooks, the visual resources are presented in the results summary section (after performing the combustion reaction experiment), to confirm the mass ratio of the component elements. **High-** and **Low**-group students mostly selected option **c**, while **Middle**-group students mostly selected option **d** for the reasons explained in the following paragraphs.

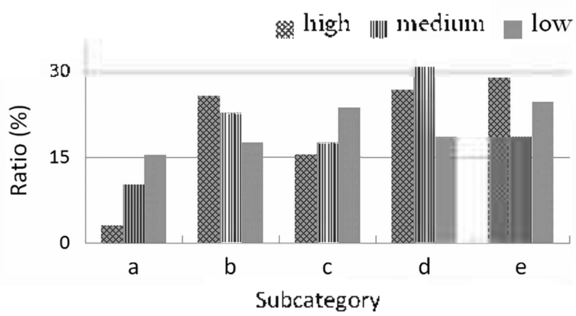

***Figure* 6.** Study of students' awareness for inquiry results and summary. **a**: Table completion using performed experiment results. **b**: Table completion using given experiment results. **c**: Graph completion using given experiment results. **d**: Table and graph completions using given experiment results. **e**: Table and graph completions using performed experiment results.

*Student A (**High**): "Deducting the experiment results by completing tables or graphs with the values of the performed experiment not only helps you understand the problems faced during the experiment procedure, but also increases your degree of satisfaction toward the obtained results, making them easier to understand."*

*Student B (**Middle**): "Completing graphs with the values obtained from calculating the amount of other reactants using the exact values given in the table allows you to know the exact mass ratio between the reactants."*

*Student C (**Low**): "Completing tables and graphs with the values measured during the experiment allows you to understand more deeply the concept of mass ratio between reactants."*

For **high**- and **low**-group students, summarizing inquiry results in tables and graphs using the values obtained after performing the inquiry experiment by themselves increased their interest and satisfaction toward the inquiry results and helped them understand more deeply the concept of definite proportions. They were interested in summarizing the results of an experiment performed by themselves and, as a result, it seemed as if they were trying to understand the contents actively. On the other hand, **middle**-group students seemed anxious about the experiment performance and results. This is considered a result of their tendency to understand the concept of definite proportions using the exact values given. Not all students simply wanted to use the given values; they wanted visual resources that would make them think more deeply about the basic concepts and principles after calculating the mass ratio of the second compound using the mass ratio of the reactant and the product of the first compound. As seen, the effectiveness of the visual resources was different within the same concept depending on the academic level of the students.

CONCLUSIONS AND RECOMMENDATIONS

In this study, the visual resources of the "Regularity in Chemical Reactions" unit of nine ninth grade science textbooks (revised 2009 version) were analyzed and classified by role. Students were surveyed on the effectiveness of the visual resources. The textbook analysis revealed that 68% of the visual resources belonged to the learning material presentation role, 14% to the motivation role, 9% to the inquiry procedure guidance role, and 8% to the inquiry results and summary role. The stoichiometric concepts presented in the "Regularity in Chemical Reactions" unit (law of conservation of mass, law of definite proportions, and law of gaseous reaction) are basic concepts that deal with the rearrangement of particles (before and after the chemical reaction) that participate in chemical reactions. The reason why this unit was selected as a subject of study was because many visual resources (such as reaction equations, photographs, and diagrams) are required to explain these concepts. Further, to complement the limitations of textual explanations, visual resources through which such concepts can be explained more easily are greatly required. The visual resources in the analyzed unit were mostly photographs (42%), and reaction equations (20%). The reason the usage of photographs was highly frequent was because photos are the best tool for depicting scientific facts and phenomena that exist in nature in textbooks and describing concepts that cannot be actually experienced or observed. Reaction equations were also very frequent because they can express stoichiometric concepts more simply and clearly than other visual resources. Cartoons, although loved by students, were used less than other visual resources. This could be why the accessibility of these concepts to students decreased.

The majority of students selected photos showing the bread-baking process as the most effective visual resource of the motivation role because they feel more interested in familiar objects or experienced contents, particularly because the concepts can be distinguished more easily. Thus, students showed more interest toward visual resources that fit their preferences and liked visual resources showing examples of things they had experienced before. In the analysis of visual resources of learning material presentation, cartoons (mass conservation concept), graphs (law of definite proportion), and reaction equations (law of gaseous reaction) were selected as the most effective visual resources. In Survey #2, diagrams (option **c**) and cartoons (option **d**) were expressed similarly. However, the students selected the cartoons. Students said that cartoons were more effective because they feel more familiar and include textual explanations, making contents easier to understand by themselves. In Survey #3, students selected graphs as the most effective visual resources because they expressed simply and clearly that the mass ratio of component elements increased uniformly, making it easier to understand that there is a proportional relationship between them. In Survey #4, students selected reaction equations as the most effective visual resource as they illustrated the relation between volume and number of moles in figures. In contrast, students did not select visual resources that are complicated or difficult to understand (such as option **b**, which showed reaction equations or reaction ratios (modular ratio, mole ratio, volume ratio) in numbers). Therefore, visual resources that fit the academic level of students must be presented. In addition, simple and original visual resources that allow students to approach difficult scientific contents easily are required.

The analysis of visual resources of the inquiry procedure guidance role revealed that students preferred photographs showing sequential experiment procedures, including simple explanations. Students were feeling anxious about the experimental procedure they were going to perform. They used photographs showing sequential experiment procedures to verify whether what they were doing was right. For students who feel anxious about the experiment they are going to perform, it is necessary to include visual resources that show the entire procedure of the experiment sequentially and in stages, to make them feel more confident. Moreover, it will reduce the vague sense of uneasiness they feel toward science.

The analysis of visual resources of the inquiry results and summary role revealed that students preferred "table and graph completion using the performed experiment results." This kind of visual resource seemed to encourage students to find out the results (as if it were a challenge) of the experiment. Further, students seemed to want visual resources that would make them think more deeply about the basic concepts and principles learned through the experiment. Contrarily, **middle**-group students wanted to summarize the inquiry results using given experiment results as a result of their concern about complicated parts of the experiment or problems that may arise from wrong procedures. As seen, for students that do not feel confident about the experiment, it is necessary to adopt visual resources that are effective for summarizing concepts and results.

There is a discrepancy between the results of the science textbooks analysis and the students' survey. Visual resources not only motivate students to learn, but also can focus their attention. In addition, they allow students to experience the learning contents indirectly, and are more effective than textual explanations. Thus, visual resources that are familiar to students and stick by the aforementioned roles must be presented. As can be inferred, when effective visual resources are used, students become more interested and feel more confident of understanding the contents.

Since science has a great impact on our daily lives, it is important to increase the interest of students toward it. To accomplish this, textbooks should be modified in accordance to the characteristics (concept- or phenomenon-centered) of the students' survey results. It is necessary to develop visual resources that consider the students' level of understanding of contents and the characteristics of the unit contents, so that visual resources can play the role of organizers or scaffolds in learning activities. The results of this study aim to: 1) present the most effective visual resources in teaching and learning activities, 2) induce the selection of textbooks in accordance with the academic achievement level of students, and 3) provide the information required to develop the most effective visual resources for the contents of each unit.

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Appendix 1. Perception research survey of visual materials for students

1. When learning about chemical and physical changes, which visual aid will present the most effective learning incentive?

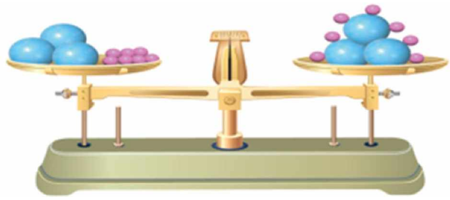
a. Picture of a lighted candle **b**. Picture of the melting stages of sugar through heat **c**. Campfire scene picture

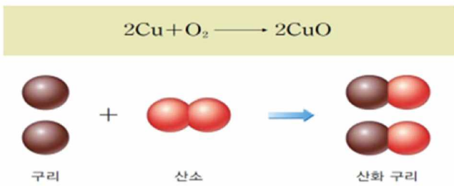
d. Bread-making process picture **e**. Breakfast preparation cartoon

Why do they think this way?

2. When learning about the law of conservation of mass, which visual aid will present the most efficient learning incentive?

a. Picture representing different placements of balls **b**. Picture of the resulting copper oxide equation





c. Diagram showing the combustion of steel wool in airtight spaces **d**. Cartoon showing the combustion of steel wool

e. Picture series showing the combustion of steel wool in open spaces

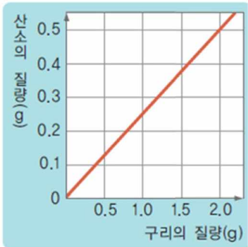
Why do they think this way?

3. When learning about the law of definite proportions, which visual aid presents the most effective learning incentive?

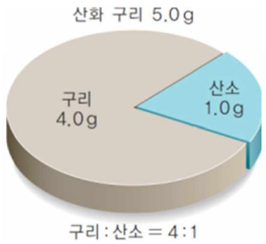
a. Picture showing the generating experiments for copper oxide

구리를 가열함

b. Copper oxide mass ratio graph

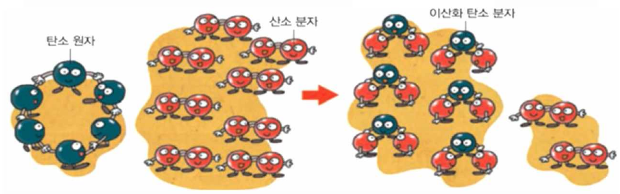


c. Copper oxide mass ratio diagram



d. Picture showing how to make sandwiches with bread and jam

e. Picture of carbon dioxide production reaction



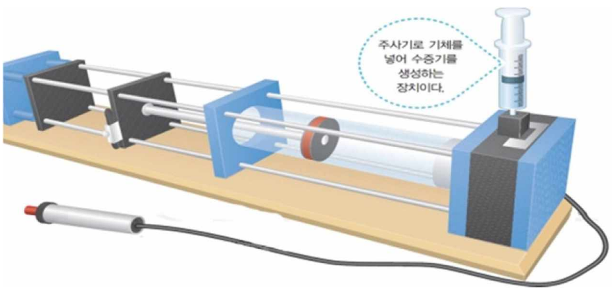
f. Table of the reaction for iron and oxygen

철의 질량(g)	1.00	2.00	3.00	4.00
산화 철(Ⅲ)의 질량(g)	1.43	2.86	4.28	5.71
철과 결합한 산소의 질량(g)	0.43	0.86	1.28	1.71
철의 질량 / 산소의 질량	2.33	2.33	2.34	2.34

Why do they think so?

4. When learning about the law of combining volumes, which visual aid presents the most effective learning incentive?

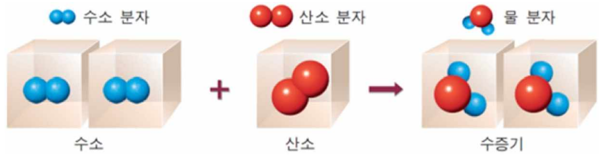
a. Picture of a device generating steam by the reaction of hydrogen and oxygen



b. Table of the before and after ratio for the ammonia-producing reaction

	$3H_2(g)$	$+ N_2(g)$	$\rightarrow 2NH_3(g)$
계수비	3	: 1	: 2
분자 수의 비	3	: 1	: 2
부피비	3	: 1	: 2

c. Reaction of the steam generation process



d. Table of the steam generation reaction

실험	반응 전 기체의 부피(mL)		반응하지 못한 기체의 종류와 부피(mL)	반응한 기체의 부피(mL)		생성된 수증기의 부피(mL)
	수소	산소		수소	산소	
(가)	5.5	2.1	수소, 1.3	4.2	2.1	4.2
(나)	16.4	8.2	없음.	16.4	8.2	16.4
(다)	22.6	22.6	산소, 11.3	22.6	11.3	22.6

Why do they think so?

5. When learning about the laws of conservation of mass, which visual aids present the most effective exploration method?

a. Picture of the experiment process and main device for a gas-producing reaction

<Experiment instructions>

1) Place a 5mm X 5mm magnesium piece using pincette in a 20 ml dropper bottle.
2) Add the maximum amount of 2% diluted hydrochloric acid and wipe the area with a paper towel.
3) After matching the electronic scale to 0, close the lid of the dropper bottle prepared during step 2, place on top of the electronic scale, and measure mass.
4) Press the lid of the dropper bottle and drop the diluted hydrochloric acid on the magnesium piece.
5) Observe the changes in mass during the reaction process.

b. Sequential photos of the experiment process and its device during the gas generation experiment.

<Experiment instructions>

1) Put approximately 1.0 g of eggshell in an Erlenmeyer flask.
2) Place 10 ml of 4% diluted hydrochloric acid in the test tube.
3) Measure the mass in the Erlenmeyer flask and test tube used in steps 1 and 2.
4) Pour the diluted hydrochloric acid from the test tube into the Erlenmeyer flash to induce reaction changes in the eggshells, and measure the mass after the reaction is completed as shown in the picture.

c. Sequential picture of the device and student during a gas generation experiment

<Experiment instructions>

1) Put the test tube filled with 10 ml of hydrochloric acid and eggshells in the PET bottle.
2) Close the PET bottle lid tightly and measure mass.
3) Tilt the PET bottle and measure mass after one minute of the reaction between the hydrochloric acid and eggshells.
4) Open the lid of the PET bottle and measure mass after 30 seconds.

Why do they think so?

6. When conducting experiments about the law of definite proportions, which visual aid will have the most effective result exploration and arrangement?

a. Table completion of the performed experiment's results

<Experiment method>
Pour 5 ml of diluted hydrochloric acid each in five test tubes, then place the magnesium pieces numbered 1 5 inside them, measure the gas reaction volume, and check if there are any magnesium ribbon pieces that did not react.

넣어 준 마그네슘 리본 조각(개)	1	2	3	4	5
반응한 묽은 염산의 부피(mL)	5	5	5	5	5
발생한 기체의 부피(mL)					
반응 후 남은 마그네슘 리본 조각의 유무					

b. Table completion of the results obtained from the experiment

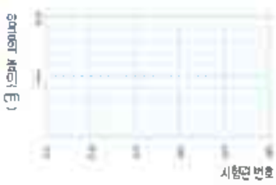
<Experiment method>
The following table shows the variation of magnesium mass and measured mass of magnesium oxide when the separate combustions were generated. Calculate the weight of the oxygen and magnesium oxide, and the oxygen mass generated from the magnesium oxide during experiments 1–3.

실험	마그네슘의 질량(g)	산화 마그네슘의 질량(g)	산소의 질량(g)	질량비 (마그네슘 : 산소)
1	0.3	0.5		
2	0.6	1.0		
3	0.9	1.5		

c. Graph completion using the obtained experiment results

<Experiment method>
After pouring 6 ml of 5% lead nitrate solution in six separate test tubes of equal size, and potassium iodine solution of the same concentration as shown in the table below, yellow sediment was generated. When the height of the generated sediment is as follows, let us show the generated sediment height inside the test tubes through a graph.

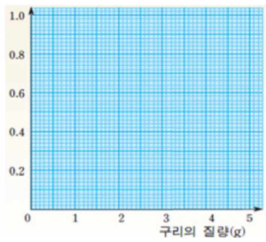
시험관 번호	1	2	3	4	5	6
질산 납 수용액(mL)	6	6	6	6	6	6
아이오딘화 칼륨 수용액(mL)	0	2	4	6	8	10
생성된 앙금의 높이(cm)	0	0.7	1.3	1.8	1.8	1.8



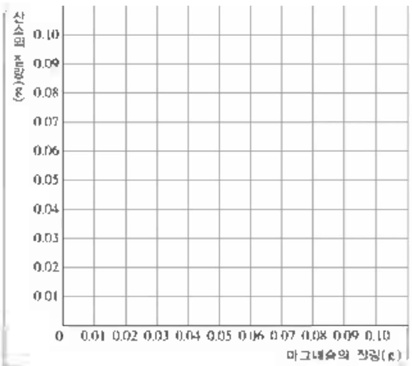
d. Table and graph completion of the obtained experiment results

<Experiment method>
The following table shows the results obtained from measuring the mass of generated copper oxide and reaction copper mass from generating copper oxide (II) and reacting oxygen with copper. How many grams are generated from each oxygen reaction in experiments 1–3? Further, let us draw a graph that shows the reaction oxygen mass in a vertical axis and the reaction copper mass in a horizontal axis.

실험	구리의 질량(g)	산소의 질량(g)	산화 구리(II)의 질량(g)
1	1.2		1.5
2	2.0		2.5
3	2.8		3.5
4	3.6		



e. Table and graph completion using the performed experiment's results



구분	마그네슘 1.5cm	마그네슘3.0cm	마그네슘 4.5cm
마그네슘 질량(g)			
산화 마그네슘 질량(g)			
산소 질량(g)			

<Experiment method>
- Put 1, 1.5, and 2 g of copper powder in the (A), (B), and (C) crucibles and measure mass.
- Heat the copper powder in the (A), (B), and (C) crucibles until they change color to black.
- When the color has completely changed to black, turn off the fire and sufficiently cool the crucibles.
- Measure the mass in crucibles (A), (B), and (C), and record it in the table.
- Draft a graph with the copper oxide mass in the vertical axis and the copper mass in the horizontal axis.

Why do they think so?