Assessing Functional Effectiveness of Pictorial Representations Used in Text

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The inclusion of visual illustrations in educational textbooks is a longstanding, practically universal practice. An examination of currently used texts at all levels of education demonstrates that, regardless of subject or level, both publishers and educators seek texts which include a variety of visual representations. In light of the heavy reliance upon visuals in textbooks, it seems appropriate that there would be empirical data to support this practice. Accordingly, several studies have been conducted which attempt to establish the relationship between pictures and accompanying text (Levie & Lentz, 1982).

It appears that the most valuable information gained from the majority of studies heretofore conducted concerning the relationship of illustrations and text is that illustrations can have a variety of significant effects, or in some cases can have no effect at all (Levie & Lentz, 1982). One reason for this is that illustrations are complex, multivariate media. The type of illustration, its relationship to the text, its physical characteristics, its placement in the text, and the purpose of its existence in the learning situation are among the variables that will have a profound bearing on its effectiveness. As noted by Schramm (1977), the differences within a medium are no less significant than those between media.

Salomon (1978) asserts that because different media are composed of a complex, flexible variety of attributes, they can be used for a variety of instructional endeavors on a variety of levels. Following Schramm's (1977) statement concerning differences

within a medium, Salomon's principle could also apply to the same medium used under different circumstances. In other words, the same illustration could be used for a variety of instructional tasks and result in a variety of learning outcomes, based upon the circumstances of its use. These various uses of the illustration would be a reflection of the comparative ability of its various attributes to be used for different tasks. Therefore, in order to assess the value of an illustration as an instructional tool when it is used in conjunction with text, each of the attributes found in the illustration and its relationships with other attributes must be examined.

Levie and Lentz (1982) identify the instructional task, or function, that an illustration is performing as another important criterion for assessment of the effectiveness of any illustration used in conjunction with text. They point out that only after a determination of function is made can a valid assessment of effectiveness, based upon attributes, occur. In other words, an illustration used in conjunction with text with no consideration as to what instructional function it is intended to serve might very well prove no more effective than no illustration; in fact, it might prove detrimental to pedagogical qualities of the text. However, the fact that much research shows a positive effect from illustrations suggests that if an illustration serves an instructional function appropriate to the intended instructional outcome, it has value as a textual supplement.

Consequently, the ability of an illustration to serve a function effectively is dependent upon, among other things, the relationship between the attributes present in the illustration and the function the illustration is intended to serve. Matching attributes to instructional functions therefore can be considered an essential step in establishing a data base for decisions about effective utilization of illustrations in text.

Studies have been conducted to begin the task of matching attributes of illustrations to specified instructional functions. This study contributes to an understanding of the relationship between attributes and functions of visual illustrations used with text by examining the effectiveness of illustrations providing analogical representation and illustrations providing literal representation in serving two specific instructional functions.

The primary hypotheses of the study were that illustrations providing analogical representation better serve the instructional function of visually clarifying abstract or nonphenomenal information, and that illustrations providing literal representation better serve the function of identifying physical properties of phenomenal information. The distinction between phenomenal and nonphenomenal information is the difference between information that does or does not have a tangible existence that can be recorded. Nonphenomenal information has no tangible existence or is too large, too small, too distant or too transient to be recorded (Knowlton, 1966). For example, voltage, which is defined as electromagnetic force and is derived by multiplying current by resistance, has no tangible existence and is therefore nonphenomenal. Phenomenal information has a tangible existence that can be recorded. For example, a resistor, which alters voltage in a circuit, is composed of tangible substances such as metal wire and plastic, and hence is phenomenal.

In terms of textbook utilization, the hypotheses of the study are that if an intended instructional function is to clarify nonphenomenal information, an illustration that provides an analogical representation is more likely to be effective, and that if the intended instructional function is to identify properties of phenomenal information, an illustration that provides a literal representation is more likely to be effective.

Analogical illustrations are defined for this study as being functionally as well as physically different from literal, or realistic, illustrations. An illustration providing an analogical representation refers to information conceptually rather than literally; that is, its features usually do not resemble the features of the information it represents. This type of illustration is effectively used when the information it illustrates is nonphenomenal. For example, the illustration in Figure 1 is an analogical illustration that demonstrates the interchangeability of and relationship between the muscles of the human body. These concepts are considered nonphenomenal because they cannot actually be seen. Nevertheless, they can be

analogized to the bell ringers as a means of clarifying them.

An illustration providing a literal representation, on the other hand, is a more salient representation of real phenomena, usually because it resembles them pictorially. Although all illustrations depart in some degree from real objects in aspects such as dimensionality or size, an illustration possessing some physical resemblance to an object establishes a more literal representation of the object than one that does not possess a physical resemblance. In other words, if the object in an illustration can be identified by the viewer as that object, the illustration is providing a literal representation. As an example, Figure 2 is a literal representation of the physical properties of the chloroplasts found in plants which, viewed under a microscope, have physical properties and hence are phenomenal.

The literal type of illustration, often referred to as realistic, traditionally has been considered instructionally effective. Recently, however, resemblance and realism have been questioned as proper criteria for judging the appropriateness of some visual materials. Salomon (1979) asserts that resemblance to a real object in visuals is at best superficial, and that the real meaning behind any communication is what is attributed to it by way of mental processes rather than a property of the message itself. Thus, for increasing comprehension, an illustration providing analogical representation might better illustrate information that would be difficult or impossible to illustrate literally, while an illustration providing literal representation might more effectively supplement an expository description of phenomenal information.

A secondary hypothesis of the study is that male and female students utilize both types of illustrations in basically the same way and with similar degrees of effectiveness. Justification for this aspect of the study stems from a lack of conclusive evidence concerning the impact of gender on comprehension and utilization of illustrations. Hortin and Sheriff (1981) assert that gender accounts for only one percent of the overall variance found in educational media research, including use of illustrations. Levin and Lesgold (1978) state that "both males and females benefit from pictures" (p. 238). However, this generalization is confined to elementary aged children, and stops short of stating that both genders benefit equally from illustrations.

On the other hand, a study by Sewell and Moore (1980) using college students found that females tended to utilize cartoon embellishments accompanying text to aid in interpretation of that text, while males tended to overlook the cartoons. Peeck,

FIGURE 1
Illustration Used as an Analogical Representation

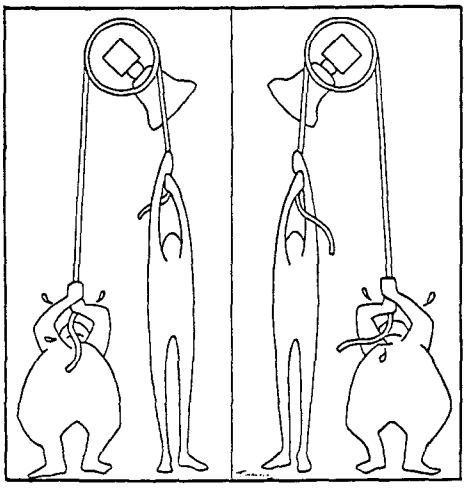
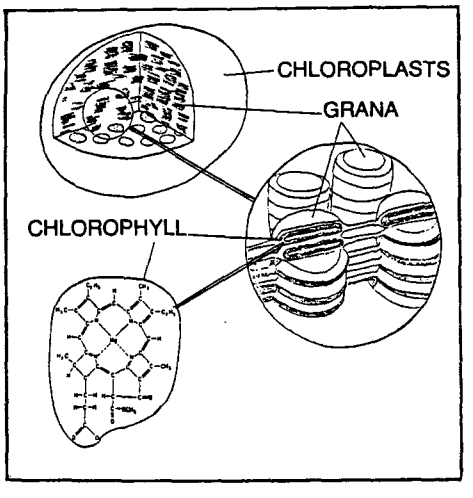


FIGURE 2
Illustration Used as a Literal Representation



(1974) also feels that females tend to use illustrations more than males.

Thus, the data concerning variations due to gender in use and comprehension of illustrations in text lack the conclusiveness necessary for establishment of generalizations or for justification of current practices. The inclusion of analysis of variance based upon gender in this study adds to the data.

METHOD

Subjects

The hypotheses were tested on 90 male and 90 female college undergraduate students, randomly selected from college general education courses. Although no such stipulation was made, most of the subjects were freshmen or sophomores, between the ages of 18 and 21. The selected students were told that they would be participating in an empirical study concerning the use of illustrations in text, and participated on a voluntary basis. Each of the two groups was equally divided into two treatment groups, so that equal numbers of subjects were represented in each of the four groups.

Since the study was a test of comparative comprehension effects, it was necessary to control as many other variables as possible. Thus, a group of college students, who are assumed to be skilled readers, allowed a more accurate assessment of the variables tested, since inability to perform well on a comprehension test could not be attributed to the subject's inability to read (Levin & Lesgold, 1978).

Materials

Two expository prose passages taken from college-level texts were used in the study, one concerning photosynthesis in plants and one concerning the structure and function of human muscles. Both passages were selected from monographs currently or recently used as college-level supplemental texts, to ensure that the passage qualified as college-level expository pieces. The passages were of comparative length, the photosynthesis passage being approximately 880 words and the human muscle passage being approximately 800 words.

Several criteria were considered in selection of the passages used, and the same criteria were used in selecting both passages. In addition to the above-mentioned criterion of length, the information presented in the passages was considered. According to Levin and Lesgold (1978), when testing with higher level subjects and curriculum-based material, it is many times more difficult to distinguish what is learned from what is already known. It was therefore decided to use passages that contained information that was commonly attainable but not overly familiar to the subjects, as determined by a pretest survey. Other selection criteria were the high level of technicality and density of information contained in a short space in the passages, which is representative of textbook information (Brody, 1981), and the presence of both phenomenal and nonphenomenal information in both passages.

The final criterion for selection of the passages was the potential for inclusion of both literal and analogical representations of the information in the passages. Both passages already had literal drawings illustrating information included in the text. Since these drawings appeared to be serving the function of identifying physical properties of phenomenal information presented in the text, they were incorporated into the study in their original format.

Analogical illustrations were created to visually clarify nonphenomenal information presented in the passages. The analogical illustrations were drawn similar to the existing literal illustrations so that all illustrations were black and white with similar amounts of detail and approximately the same size.

One illustration was placed within each passage. One illustration per 700–900 words is within an illustration-to-word ratio established in a pre-experimental survey of randomly selected college texts. To maintain the integrity of the illustration-text relationship, cues to utilize the illustrations were inserted at appropriate locations in the textual passage, based upon the type of representation being cued. Thus, specific information, either phenomenal or nonphenomenal, was reinforced in the text by directing the reader to the illustration at that point. The following example from the photosynthesis passage containing the literal illustration demonstrates the cueing technique utilized.

As shown in the illustration on page 2, the chlorophyll molecule is a complex organization of carbon, hydrogen, nitrogen and oxygen atoms surrounding a magnesium atom.

This passage referred the subject to the illustration depicted in Figure 2. In the same passage containing the analogical illustration, this sentence was written:

The chlorophyll molecule is a complex organization of carbon, hydrogen, nitrogen and oxygen atoms surrounding a magnesium atom.

The analogically illustrated passages contained cues appropriate to the information represented by the illustrations. For example, the analogically illustrated human muscle passage contained the following sentence:

As depicted in the illustration on page 2, when muscles contract, they become shorter and thus exert a pull on their attachments.

In the same passage containing the literal illustration, this sentence was written:

When muscles contract, they become shorter and thus exert a pull on their attachments.

The illustrations were contained on the second page of each of the passages, and were accessible from the text at all times. In all cases, two specific references to the illustration were made within the passage. Use of the illustrations by the subjects was not restricted.

Two ten-question tests were created, one to accompany each of the passages. Each test contained questions concerning information found only in that passage. Each test consisted of five multiple-choice questions relating to phenomenal information in the passage and five multiple-choice questions relating to nonphenomenal information in the passage. The questions were arranged so as to achieve a balance between information hypothesized to be more positively affected by illustrations providing literal representation, and information hypothesized to be more positively affected by illustrations providing analogical representation. If the question concerned information that could be physically sensed, and therefore visually represented an object in a relatively literal sense, it was addressing phenomenal information. If it concerned information that could not be visually recorded because of its abstract nature or because it was too large, too small, or too transient to be recorded, it was addressing nonphenomenal information.

To assess test reliability, a pilot test was given to 20 students who read each of the passages and answered each of the questions. For each passage, half of the subjects utilized an illustration providing literal representation and half utilized an illustration providing analogical representation. The Pearson Product-Moment Correlation Coefficient was used to determine a test reliability of .87 for the photosynthesis passage and a test reliability of .81 for the muscle passage.

Procedures

Following the pilot study, the hypotheses were tested by assigning the selected passages to the two groups of students in two separate testing periods. In the initial period, one group read a passage utilizing an illustration depicting an analogical representation, while the other group read the same passage utilizing an illustration depicting a literal representation. The students were instructed to read the passage and then, after turning the passage in, answer the ten questions concerning the information they had read. There was no time constraint on the students for reading the passage or for answering the questions.

At the second meeting, the second passage was assigned to both groups with the same instructions as those given at the first meeting. This time the group that read the first passage with an illustration providing literal representation was given a passage with an illustration providing analogical representation, and the group that read the first passage with an illustration providing analogical representation was given a passage with an illustration providing literal representation. Thus, the data collected represented responses from both groups using the same media format to complete different tasks.

An experimental design was developed that divided the program by task (reading each of the passages) and medium (the type of representation contained in each of the passages read). The two treatment groups interacted at various times with each of the two media formats, but performed a differ-

ent task with each. In other words, comparable groups of learners worked on the same two-task program, with each group exposed to different task-medium combinations. One value of this design is that the order in which groups performed the tasks could be varied. Another is that it allowed an assessment of the specific medium most appropriate for each task, and each component within each task individually. This was accomplished by entering both groups into both treatments. Figure 3 depicts the structure of the design.

Two separate three-way analysis of variance tests were performed on the data. The passage variable was not incorporated into a single ANOVA, in order to isolate interactions between other variables, and also because the experiment was not a comparison of comprehension of the two passages per se. Any possible loss of information occasioned by not testing this interaction is offset by the increase in power and ability to generalize brought about by the replication aspect of the study.

The analysis of variance tests divide the groups by task and treatment for each passage. A third division, gender of subjects, was used to test for any possible interaction between task and gender or treatment and gender. Thus, the three-way design incorporates type of illustration, type of question, and gender variables into a factorial analysis.

FIGURE 3
Structure of Study Design

GROUP 1	GROUP 2
Task 1	Task 1
A	B
Task 2	Task 2
B	A

Task 1 = Reading a passage concerning photosynthesis
Task 2 = Reading a passage concerning human muscles
A = Passage with literal illustration
B = Passage with analogical illustration

RESULTS

Comprehension performance tests were statistically analyzed for each passage separately. Raw scores and mean scores for the photosynthesis passage are shown in Table 1. The photosynthesis passage analysis of variance, shown in Table 2, demonstrates that the interaction between treatment and test was significant, $F(1,176) = 83.34$, $p<.01$.

As illustrated in Table 2, there were no significant differences for the main effects of treatment, gender, and test. There was a significant difference for the treatment × test interaction, which reflects the ability of subjects to respond correctly to different types of questions depending on the type of illustration provided in the passage. All other interactions were nonsignificant.

The data support the rejection of both the null hypotheses concerning the interaction between test and treatment. They indicate that there was a significant difference in ability of subjects to respond correctly to questions of a phenomenal and a nonphenomenal nature, depending on the type of illustration utilized in a passage. Specifically, in a textbook passage concerning photosynthesis of plants, more questions of a nonphenomenal nature were answered correctly by subjects who read the passage that utilized an illustration providing analogical representation than by subjects who read the same passage with an illustration providing literal representation. Conversely, those students who read the passage that utilized the illustration providing literal representation answered more questions of a phenomenal nature correctly than did those reading the passage that utilized the illustration providing analogical representation.

The data also demonstrate that there was no significant difference between males and females concerning the utilization of the illustrations. This indicates that the generalization concerning picture utilization can be made across genders.

The data derived from the replication test performed after reading the passage concerning the parts and functions of the human muscle support the results of the photosynthesis test. Raw and mean scores are reported in Table 3.

The analysis of variance performed on the data, shown in Table 4, again identifies the interaction between treatment and test as

TABLE 1
Raw Scores and Mean Score Totals Test over Photosynthesis in Plants*

	Literal Illustrations				Analogical Illustrations			
	Nonphenomenal		Phenomenal		Nonphenomenal		Phenomenal	
	male	*female*	*male*	*female*	*male*	*female*	*male*	*female*
raw score	138	130	171	177	168	162	133	129
mean score	3.07	2.87	3.80	3.93	3.37	3.60	2.96	2.87
combined mean score	2.98		3.87		3.67		2.91	

*for each subgroup, $N = 45$

TABLE 2
Photosynthesis in Plants Passage Analysis of Variance, $N = 180$

Source	*SS*	*df*	*MS*	*F*
Between Groups	264	179		
Treatments	1.61	1	1.61	1.08
Gender	0.41	1	0.41	.28
Treatment X Gender	0.17	1	0.17	.11
Groups w/Treat, Gender	261.81	176	1.49	
Within Groups	190.50	180		
Tests	0.41	1	0.41	.56
Treatments X Tests	60.84	1	60.84	83.34*
Tests X Gender	0.70	1	0.70	.96
Treat X Test X Gender	0.41	1	0.41	.56
Tests X Groups w/ Treatments X Gender	129.14	176	0.73	
Total	454.50	359		

*$p < .01$

TABLE 3
Raw Score Totals and Mean Scores Test over the Human Muscle*

	Literal Illustrations				Analogical Illustrations			
	Nonphenomenal		Phenomenal		Nonphenomenal		Phenomenal	
	male	*female*	*male*	*female*	*male*	*female*	*male*	*female*
raw score	153	149	186	187	184	180	152	144
mean score	3.40	3.31	4.13	4.16	4.09	4.00	3.38	3.20
combined mean score	3.36		4.14		4.04		3.29	

*for each subgroup, $N = 45$

TABLE 4
Parts and Functions of the Human Muscle Analysis of Variance, $N = 180$

Source	*SS*	*df*	*MS*	*F*
Between Groups	308.87	179		
Treatments	0.62	1	0.62	.35
Gender	0.62	1	0.62	.35
Treatments X Gender	0.23	1	0.23	.13
Groups w/Treat, Gender	307.40	176	1.75	
Within Groups	175.50	180		
Tests	0.02	1	0.02	.03
Treatments X Tests	53.68	1	53.68	77.80*
Tests X Gender	0.01	1	0.01	.01
Treat X Test X Gender	0.22	1	0.22	.32
Tests X Groups w/ Treatments X Gender	121.57	176	0.69	
Total	484.37	359		

*$p < .01$

significant, $F(1,176) = 77.80$, $p<.01$. The analysis of variance indicates a lack of significant difference for main effects of treatment, gender, and test, and for all interactions except the treatment × test interaction. Again, there is a significant difference in ability of subjects to respond correctly to questions of a phenomenal and a nonphenomenal nature, depending upon the type of illustration utilized in conjunction with the text.

Lack of any significant difference within groups or of any interaction other than that between treatment and test in either analysis of variance indicates that in each situation the illustration was performing a specific instructional function that was not being served by the other type of visual illustration, and that males and females profitted similarly from the treatments.

DISCUSSION

The data generated in this study support one of the basic premises of the functional approach to research on illustrations: functions served by illustrations must be viewed in terms of specific and precise instructional roles rather than more general instructional goals or outcome statements (Brody, 1983). In this study, illustrations were selected to serve two specific functions, with the intent of the selection and subsequent utilization being to aid in the achievement of an instructional outcome. Specifically, one illustration was selected to identify properties of phenomenal information introduced in an expository prose passage and one illustration was selected to clarify nonphenomenal information introduced in an expository prose passage. These are two examples of instructional functions which can be served by illustrations, viewed in terms of precise and specific instructional roles. The expected instructional outcome to be aided by these functions was comprehension of the prose passages read in conjunction with the illustrations.

Results of comprehension tests from both passages indicate that the illustrations served specific instructional functions. The group that read the passage with an illustration which served the function of identifying properties of phenomenal information did significantly better on comprehension of that type of information than did the group reading the passage with an illustration serving another function. Conversely, the group reading the passage with an illustration which served the function of clarifying nonphenomenal information did significantly better on comprehension of that information than did the other group. Thus, it can be concluded that, while both illustrations assisted in the overall comprehension of the passage, they served dif-

ferent functions to achieve that assistance, by addressing different types of information. Analysis of the data indicates that different types of information were more effectively comprehended, depending upon the illustration used with the passage.

Based upon the results of the empirical tests, it appears that there was no significant difference between the ability of male and female students to utilize the illustrations for the specified instructional functions of this study. It therefore could be concluded that for college-aged students, no gender distinction is necessary when selecting illustrations to fulfill instructional functions.

Thus, the relationship between the instructional function served by an illustration and the instructional outcome aided by that function can be compared to the relationship between "means" and "end." Functions provide the means of achieving instructional ends. Further, the success or failure of an illustration to serve an instructional function depends, among other things, upon the selection of an illustration appropriate for that function and the effective implementation of that function in the text.

Data derived from this study concerning selection of illustrations to serve specified instructional functions indicate that there is an interaction between the type of representation provided by the illustration and the instructional function served by the illustration. Specifically, an illustration providing analogical representation, which, as defined in this study, acts as an abstract representation of information, helps to clarify abstract or otherwise nonphenomenal information. Similarly, an illustration providing literal representation, which usually denotes a salient resemblance to physical objects, helps to identify phenomenal information. Thus, it can be concluded that in some cases achievement of different instructional functions may require the use of different types of illustrations.

Recommendations for Further Study

The results of this study support the need for more extensive investigation concerning instructional functions served by illustrations in relationship to textual material. Tests similar to this one need to be conducted with students at various educational levels. For example, information as to what level can effectively use illustrations providing analogical representation would add significantly to the understanding of functional services of illustrations as well as many related areas of concern. Another area of investigation concerns the academic subjects introduced in the textual passages. Illustrations providing analogical representation and those providing literal representation should be created for subject disciplines outside the pure sciences, to increase ability to generalize and extend understanding of circumstances under which these representational types of illustrations can effectively serve instructional functions. Assessments should be made as to which subject disciplines lend themselves to the types of illustrations serving these functions.

There is also a need to conduct studies concerning the use of different types of representations serving functions identical or similar to the ones served in this study. For example, it would be valuable to know whether representations other than those providing analogical representation would clarify nonphenomenal information effectively. This effort should, of course, be conducted with a wide variety of representational forms. Closely related studies using a variety of representational formats which serve instructional functions other than the ones utilized in this study also are needed.

Tests could be constructed to see whether two illustrations, each serving a different function within a passage, would contribute more toward the achievement of instructional outcomes than one illustration serving one function. The basis of this hypothesis would be that instructional outcomes cannot necessarily be achieved in their entirety through achievement of one function. In many cases, a number of different functional operations, both pictorial and nonpictorial, may be needed to achieve an instructional outcome.

It would also be relevant to test whether a number of different functions could be served by the same illustration. For example, the illustration that served the function of identifying phenomenal information

might also have served the function of emphasizing a point, providing examples, or directing attention.

Studies also are necessary to assess the effectiveness of illustrations serving functions with literary forms other than expository prose. This would involve the application of various representational types to various functional operations for each of the literary forms investigated.

In short, the conclusiveness of the results of this study both necessitates and facilitates further investigation into this aspect of pictorial research.

CONCLUSION

Recent literature concerning the use of illustrations in text has stressed the need for an assessment of the instructional function being served by the illustration. When an illustration is incorporated into textual matter, it should be serving a specific, pedagogically sound instructional function. Otherwise, the reader probably will not benefit from the illustration's inclusion in the text; in fact, the reader might be distracted from the text by the illustration, with no cognitive gain being derived from this distraction. Therefore, to the traditional criteria for selection of illustrations used with text must be added the instructional function that is to be served.

To determine whether an illustration will serve an intended instructional function effectively, a close examination of both the illustration's attributes and its relationship to the text must be made. Research has shown that illustrations are composed of a variety of attributes pertaining to physical, instructional, and relational qualities of the illustrations, and that these attributes affect the way in which illustrations can be used as instructional tools. Therefore, the attributes present in an illustration will account in part for its effectiveness in serving an instructional function.

The findings of this study suggest that illustrations possessing literal representation are more effective than illustrations possessing analogical representation when the instructional function to be served is identification of properties of phenomenal information, and that illustrations possessing analogical representation are more effective than illustrations possessing literal representation when the instructional function to be served is clarification of nonphenomenal information.

Thus, this study is one of many needed to provide a comprehensive analysis of illustrations functioning as instructional supplements to text. Until a thorough understanding of the relationship between attributes and functions of illustrations is achieved, textbooks will in all probability continue to include illustrations which do not fulfill their instructional potential.

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