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AUTHOR	Vachon, Myra K.; Haney, Richard E.
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ABSTRACT

Classroom teachers frequently express concern that textbooks and other curriculum materials are too difficult for their students. The objectives of this investigation were to develop a method for scoring the Level of Abstraction (LOA) of science reading material, and explore its relationship with certain other known methods for assessing curriculum materials (passage readability level, student cloze score, and teacher prediction of students' level of comprehension). Also examined were relationships between students' cloze scores and passage readability levels. The study was based upon nine passages taken from life, earth, and physical science textbooks written at three different levels. Non-significant correlations were found between: (1) passage LOA and passage readability; (2) student cloze scores and passage LOA; (3) passage LOA and teacher prediction of student success; and (4) student cloze scores and passage readability level. However, the consistent and high, but non-significant correlations between LOA and cloze scores combined with the fact that the LOA is based upon deep structure rather than surface structure of written material indicate the importance of further investigation of the LOA in its relationship to student comprehension of written material. (Author/TW)

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A procedure for Determining the
Level of Abstraction of Science Reading Material

Myra K. Vachon
Department of Elementary and Secondary Education
Milwaukee Public Schools, Milwaukee, Wisconsin

Richard E. Haney
Department of Curriculum and Instruction
University of Wisconsin-Milwaukee

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Abstract

Classroom teachers frequently express concern that textbooks and other curriculum materials are too difficult for their students. One criterion for textbook selection has been readability level; however, the grade level designation does not necessarily reflect the cognitive demand that concepts within the textbook passages place on students or how well they comprehend the material.

The objectives of this investigation were to: (a) develop a method for scoring the Level of Abstraction (LOA) of science reading material, and (b) explore its relationship with certain other known methods for assessing curriculum materials (passage readability level, student cloze score, and teacher prediction of students' level of comprehension). Also examined were relationships between students' cloze scores and passage readability levels.

The study was based upon nine passages taken from life, earth, and physical science textbooks written at three different levels. Data were collected to obtain preliminary agreement from science educators in the classification of concepts, determine interscorer reliability, and compare student and passage variables. Participants consisted of 24 science educators, 60 science teachers from elementary, middle, and high schools, and 425 urban students in Grades 5, 7, and 10. Instruments used were: (a) the procedure to determine level of abstraction developed in this study, (b) the cloze procedure, and (c) "Reading Level Analysis: Programs for Teachers," a published computer program which calculates readability levels based upon several well-known methods.

Level of Abstraction (LOA) of printed material is defined as the ratio of postulational or not concrete concepts to the total number of concepts in a written passage expressed as a percent, and is conceptually independent of readability level.

Non-significant correlations were found between: a) passage LOA and passage readability level, b) student cloze scores and passage LOA, c) passage LOA and teacher prediction of student success, and d) student cloze scores and passage readability level. However, the consistent and high, but non-significant correlations between LOA and cloze scores combined with the fact that the LOA is based upon deep structure rather than surface structure of written material indicate the importance of further investigation of the LOA in its relationship to student comprehension of written material.

Purpose of the Study

Classroom teachers frequently express concern that textbooks and other curriculum materials are too difficult for their students. Researchers have found that a large number of adolescents and adults are not functioning at the formal operational level (e.g., Lawson & Renner, 1975; Karplus, 1979; Shayer & Adey, 1981), yet curriculum materials contain much that is written at that level. Efforts to provide a better match are being made (Karplus, et al., 1979; Brooks, Fusco & Grennon, 1983; Shayer & Adey, 1981; Fumo, 1984). Important for this purpose is the determination of the level of cognitive demand of curriculum materials. One criterion for textbook selection has been readability level; however, the grade level designation, which is generally based on word and sentence length, does not necessarily reflect the cognitive demand that concepts within the textbook passages place on students or how well students comprehend the material.

The objectives of this study were to: (a) develop a method for scoring the level of abstraction (LOA) of science reading material, and (b) explore its relationship with certain other known methods for assessing curriculum materials including readability formulas (Jerman & Kropf, 1982), the cloze procedure (Herber, 1978, p. 237), and teacher prediction of student success in comprehending written passages. Also examined were relationships between students' cloze scores and passage readability levels.

Definitions

Level of abstraction (LOA) is defined in this study as the ratio of the number of postulational/not concrete concepts (NC) to the total number of concepts (C + NC) in a passage from printed materials expressed as a percent (LOA = NC/(C + NC) X 100). Three terms used throughout the description of the procedure to determine LOA are concept, descriptive (or concrete) concept, and postulational (or not concrete) concept. Concept refers to an idea of an object, action, or event. According to Klausmeir, Ghatala, and Frayer (1974), "concepts are fundamental agents of thought for human beings from early childhood through adult" (p. 1). Descriptive or concrete concepts are concepts whose referents can be experienced directly by scientists or other competent observers. One's understanding of this type of concept is based on direct experience with phenomena or the use of instruments that extend the range of the senses (e.g., telescopes). Examples include table, rock, and comet. Benjamin (1955, p. 56) related this type of concept to the listing and describing of data. Postulational or not concrete concepts are concepts whose referents cannot be experienced directly by anyone. They must be understood in terms of other concepts, functional relationships, inferences, and/or idealized models. Examples include atom, density, light-year, and plate tectonics. Benjamin (1955) stated that these "concepts involve the use of methods of construction, inference, and insight or creative imagination" (p. 56).

Readability level of a passage is a determination of the level of difficulty of text material usually stated in terms of grade level (Herber, 1978, p. 16). This value is determined independent of the reader and takes into consideration the surface features of the passage, such as word and sentence length.

The cloze procedure involves omitting words from a passage at regular intervals and requires the reader to determine from the context of the remaining words what these omitted words are. Success at this task has been shown to be a measure of a reader's comprehension of the material (De Santi, 1986). This score takes into consideration the deep structure of the passage as well as context clues. A low score indicates that the passage is difficult for the reader to comprehend.

Teacher judgement of a student's level of success interacting with text material is a subjective observation that a student can read and understand text material. This opinion is based upon knowledge about both the student and the written passages.

Thus, variables explored in this study were: (a) student cloze scores, (b) passage readability levels, (c) passage level of abstraction (LOA) scores, and (d) teacher prediction of student success on the cloze tests.

Hypotheses

The following hypotheses were tested at a $p<.05$ level of significance.

1. There is no significant correlation between mean readability levels and LOA scores for passages from life, earth, and physical science textbooks.
2. There is no significant correlation between mean cloze scores of students and LOA scores for passages from life, earth, and physical science textbooks.
3. There is no significant correlation between LOA scores of the passages and students' level of success in comprehending the three passages as predicted by their teachers.
4. There is no significant correlation between cloze scores of students and readability levels of passages from life, earth, and physical science textbooks.

Procedures

Nine samples of reading material were identified. These passages were selected from life, earth, and physical science textbooks intended for students in Grades 5, 7, and 10. These correspond with the grade levels of students who participated in the cloze testing. For each grade, one passage was selected from a life science textbook, one from an earth science textbook, and one from a physical science textbook. Each passage was approximately two hundred words in length and was selected from books not currently being used by the students participating in the study. Data were collected by determining the readability levels of these sample textbook passages, determining LOA scores for the passages, estimating students' level of success in comprehending the passages, and administering cloze test versions to groups of students.

The computer program, "Reading Level Analysis: Programs for Teachers" (Jerman & Kropf, 1982), which calculates readability levels based upon the Fog Index, Dale-Chall Index, Fry Graph, and Flesch Grade Level was used to determine the readability level of passages analyzed in this study. Mean readability levels were then calculated.

Following an extensive review of the literature (Vachon, 1987), the concept of LOA and the procedures for scoring passages were developed. See Appendix. These procedures were validated by having a group of science educators examine the method for identifying the concrete (descriptive) and not concrete (postulational) concepts in samples of textbook passages. The percentage of agreement among the 24 educators who classified the concepts was determined.

For the purpose of determining the LOA, concept was defined as an object, event, or action (e.g., rock, photosynthesis, measuring). These ideas are communicated in print by a noun or verb and its respective modifier(s). In classifying concepts, the context in which the concepts are written was carefully considered. Classification of concepts as either concrete or not concrete was based on their operational definitions.

Using responses from the science educators, tentative LOA scores (TLOA) were determined for each of the passages by identifying concepts in each of the 200-word sample passages, classifying the concepts as either concrete or not concrete, and then determining the ratio of the number of not concrete concepts to the total number of concepts in the sample passages times 100.

Samples of science teachers were also asked to score the passages using written directions only. A total of 60 teachers responded. The consistency among LOA scores obtained by teachers was examined by comparing the standard deviation of scores for each passage. In addition, Cronbach's alpha (Crocker & Algina, 1986, p. 138; SPSS-X, 1983) was used to determine interscorer consistency among teachers scoring passages for each science area (life, earth, and physical). Because of the variability in scoring among teachers, detailed analysis of the responses provided by the teachers for each passage was completed to identify the sources of variation and also to obtain a composite LOA score (CLOA) based upon transformations made to cast out the effects of obvious scoring errors.

Cloze passages were administered to students at Grade Levels 5, 7, and 10 in nine public schools in a medium-sized urban school district. Descriptions of student population samples are presented in Table 1.

Table 1

Description of Classes in Which Cloze Tests Were Administered

Descriptor	Grade level 5	7	10	All
n	85	176	164	425
Age range	10-13	12-14	14-18	10-18
Age mean	11.2	12.9	15.8	13.7
% male	45	53	48	49
% female	55	47	52	51
% black	58	74	43	51
% non-black	42	26	57	49

The 11 classroom teachers followed set directions which instructed them to: (a) record the names of their students; (b) read the three selected passages without deletions; (c) predict how well they thought each of their students would comprehend each passage and record a 3, 2, or 1 indicating high, medium, or low success, respectively; (d) read to their students the directions for filling in the 5th-word deletion cloze passages; (e) administer the practice cloze test one day; and, then (f) administer the cloze test consisting of three passages the next day. Materials were then returned for scoring. The exact word replacement method of scoring (Jongsma, 1980, p. 18) was used; however, misspelled words were accepted. The percent correct was computed and recorded.

The hypotheses were tested using both TLOA and CLOA scores by applying Pearson's Product Moment Correlational analyses which specified pairwise deletion of missing data and 2-tailed tests of significance.

Results

Preliminary validation of the LOA produced a high level of agreement ranging from 87% to 92% among science educators who were asked to respond to the dichotomous classification of concepts in three of the sample textbook passages.

Standard deviations found when analyzing the teacher-determined LOA scores for each of the nine passages varied widely. Cronbach's alpha coefficients ranged from .24 to .75, also indicating varied reliability among teachers using only written directions to score the different passages.

Pearson's Product Moment Correlation Coefficients between pairs of variables are shown in the following tables: (a) LOA scores of the science passages and their readability levels - Table 2, (b) LOA scores of the passages and students' mean cloze scores - Table 3, (c) LOA scores of the passages and students' mean levels of success predicted by their teachers - Table 4, and (d) mean readability levels of passages and students' mean performance on cloze tests - Table 5. The negative correlations between pairs of variables in Tables 3, 4, and 5 were expected because of the reversed scales of the variables being compared. TLOA scores (determined using feedback provided by science educators) and CLOA scores (determined by casting out obvious scoring errors of teachers) were both used in the analyses.

As shown in Table 2, correlations between LOA scores and readability levels within grade levels tended to be medium-low, except for the Grade 7 passages. Across grade levels, the passages are not ranked in the same order by either the TLOA or CLOA scores; and, they are ranked in a third way by the readability scores. This leads one to suspect that readability and LOA are measures of different characteristics.

Table 2

Correlations Between LOA Scores and Readability Levels of Science Passages

Grade	Readability level	TLOA		CLOA	
5 (n=3)					
Life	5.0	20		26	
Earth	6.2	17	r= .29	34	r= .44
Physical	6.3	27		26	
7 (n=3)					
Life	11.0	52		41	
Earth	5.3	25	r= .94	18	r= 1.00*
Physical	6.6	21		25	
10 (n=3)					
Life	9.1	20		20	
Earth	7.9	37	r= .39	34	r= .35
Physical	10.4	47		41	
All (n=9)		r= .80**		r= .65	

$*p<.05$. $**p<.01$.

Overall, consistency among teachers using only written directions varied and the coefficients based upon CLOA scores were not as high as those in correlational analyses using TLOA scores.

When the relationship between student cloze scores and LOA scores was examined, it was found that correlations using TLOA were medium-high to high, while only the correlation using CLOA scores for Grade 10 was high. See Table 3. The high correlations could indicate that the LOA measures an important factor which contributes to a student's comprehension of printed materials. Because the cloze test measures student interaction with the reading materials and involves student characteristics such as motivation and interest, significant correlations may not be reasonably expected.

Table 3

Correlations Between LOA Scores of Science Passages and Students' Mean Cloze Scores

Grade	Cloze	TLOA		CLOA	
5 (n=3)					
Life	35.0	20		26	
Earth	31.9	17	r= -.87	34	r= .30
Physical	21.5	27		26	
7 (n=3)					
Life	31.3	52		41	
Earth	33.4	25	r= -.77	18	r= -.44
Physical	40.1	21		25	
10 (n=3)					
Life	51.0	20		20	
Earth	44.3	37	r= -.93	34	r= -.92
Physical	29.2	47		41	

*p<.05. **p<.01.

The high correlations between mean levels of success predicted by teachers and TLOA scores at Grades 5 and 7, and CLOA scores at Grade 7 may indicate that the teachers recognized the abstractness of the passages and considered this characteristic when making their predictions of students' success in comprehending the material. See Table 4.

Table 4

Correlations Between LOA Scores of Science Passages and Students' Mean Levels of Success Predicted by Their Teachers

Grade	Level of Success	TLOA	CLOA
5 (n=3)			
Life	1.9	20	26
Earth	1.8	17 r= - .85	34 r= - .26
Physical	1.7	27	26
7 (n=3)			
Life	1.6	52	41
Earth	1.7	25 r= - .93	18 r= -1.00**
Physical	1.7	21	25
10 (n=3)			
Life	1.7	20	20
Earth	1.9	37 r= - .12	34 r= - .07
Physical	1.6	47	41

*p<.05. **p<.01.

When the relationship between readability of the passages and cloze scores of students based on these passages was examined, two of the three correlations were found to be medium-high (r=-.65 and r=-.73 at Grades 5 and 10, respectively), and the third much lower (r=-.51). See Table 5. Because the cloze scores do not correlate as highly with readability as they do with LOA scores, one could suspect that the characteristics used in calculating readability do not influence reader comprehension as much as the level of abstraction at which a passage is written.

Table 5

Correlations Between Mean Readability Levels of Science Passages and Students' Mean Performance on Cloze Tests

Grade		Readability level	Cloze score
5	(n=3)		
	Life	5.0	35.0
	Earth	6.2	31.9 r= -.73
	Physical	6.3	21.5
7	(n=3)		
	Life	11.0	31.3
	Earth	5.3	33.4 r= -.51
	Physical	6.6	40.1
10	(n=3)		
	Life	9.1	51.0
	Earth	7.9	44.3 r= -.65
	Physical	10.4	29.2

*p<.05. **p<.01.

Interpretations

The cloze inventory measures the reader's: (a) reading comprehension, (b) logical language production, (c) ability to deal with the grammatical structures of printed language, (d) word recognition, and (e) word identification (De Santi, 1986, p. 1). This was borne out in this study. Further reinforcement for this interpretation was found in studying the relationships between the cloze scores and teacher predictions of student success in comprehending written passages, and the students' reading levels and the cloze test scores (Vachon, 1987). It can be assumed that teachers make their predictions based upon their knowledge about a student's reading ability and other factors such as motivation.

The LOA seems to be related to these five student abilities measured by the cloze procedure. As a result of this study, one is led to suspect that the LOA, which is based on the deep structure of the written passage, is tapping a factor which contributes to student comprehension of written materials.

Training and practice appear to be important factors in improving interscorer reliability among teachers who follow the procedure for determining the LOA.

Conclusions

Because written curriculum materials, particularly the textbook, are basic tools in most science classrooms, students must be provided with materials that take into consideration the cognitive level of the reader for whom they were written. Classroom teachers are in a position to know the characteristics of their students and can judge how well their students will comprehend selected passages particularly when the teacher recognizes the cognitive demand of the written material. Knowledge about particular students may not be available to individuals responsible for selecting textbook materials; therefore, methods for assessing the characteristics of written material are important.

Readability formulas are widely used by educators to determine the appropriateness of textbooks and other curriculum materials for students at different grade levels. However, because these formulas are based on word and sentence length, the grade level designation can be easily manipulated without altering the conceptual demand the reading material places on the reader. Readability formulas focus on the surface structure of printed materials and do not necessarily present accurate estimates of a student's ability to comprehend a written passage. Results from cloze tests provide a more accurate assessment of the cognitive demand of written material on students, but the method requires time to test groups of students and scoring several passages. On the other hand, LOA scores are independent of any student performance, but still appear to be closely related to the actual performance of students on cloze tests.

Further study will determine the usefulness of the LOA procedure for assessing science reading materials and providing guidelines for authors writing curriculum materials for our students.

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Appendix:

Procedure for Determining the Level of Abstraction of Science Reading Material

1. Read a passage 200 words in length and underline each noun or verb phrase that stands for a concept, but omit all structural words, such as: articles (e.g., a, an, the); conjunctions (e.g., and, but, or, nor, because); prepositions (e.g., in, at, for, on, with); and forms of the linking verb "to be" (e.g., be, am, are, was).

   a. Note: When a concept extends to the next line, draw an arrow to indicate the connection (e.g., series circuit in the example in part c).

   b. Special Situations:

      1) Chemical or mathematical symbols and formulas - count as words.
      2) Chemical or mathematical equations - count as sentences.
      3) Idioms (e.g., kick the bucket which means die) - count as a single unit.
      4) Gaps/ deletions (e.g., doesn't have holes in "Pumice has holes, but granite doesn't.") insert the missing word(s) and include the concept in the count.
      5) Fillers/ insertions (e.g., There in "There are three boys going skating.", inasmuch, consequently) - do not count.
      6) "Of" phrases which can be transformed into noun phrases (e.g., height of a tree meaning tree's height) - count as a single unit.
      7) Pronouns - count except in relative clauses (e.g., who in "The man who came late was my father.").

   c. Example: Becky's lamp is not wired with a series → circuit. If it were*, all the light bulbs would be unlit. In a series circuit, the current cannot pass through a burned-out bulb to reach the others. The light bulbs in Becky's lamp are connected in a parallel circuit. In a parallel circuit, there is more than one path for the current to take.

*meaning were wired

2. Reread the passage carefully.

   a. Consider the context in which the concepts are written, and classify each concept as either C for concrete or NC for not concrete using the following definitions:

      1) concrete (C) means the concept has referents which can be experienced directly by scientists and other competent observers. They are understood based on direct experience with phenomena or the use of instruments that extend the range of the senses (e.g., telescopes) - leave underlined. (Examples: table, chair, rock, moon, water, look.) Do not try to judge whether or not the intended reader can experience the concept by direct observation.
      2) not concrete (NC) means the concept has referents which cannot be experienced directly by anyone. They must be understood in terms of other concepts, functional relationships, inferences, and/or idealized models - underline again. (Examples: atom, density, mole, ideal gas, light-year, plate tectonics).

   b. Important:

      1) Context - Consider the meaning within the context of the passage because some concepts can be either C or NC. "Temperature" is an example. When "temperature" is used to refer to the hotness or coldness of an object, it is C. When temperature is used in terms of the speed at which molecules move, it is NC.
      2) Analogues and other models - These may aid in concept understanding, but themselves are usually not concrete even though they may be used to clarify an NC concept (e.g., reference to rocks as radioactive clocks).
      3) Processes or actions - Even though the result can be experienced, the process or action itself may still be NC. (For example, we can see a bulb light up because of the electrical current running through the wires, but the current of electrons is NC.)
      4) Pronouns or references made to previous concepts - Look at the antecedent (word or phrase). If any part of the antecedent is NC, mark the pronoun NC (see number 5 in EXAMPLES below).
      5) Historical names and dates - Consider as NC.

c. EXAMPLES: Some rocks[1] found[2] in the earth[3] are over a million years old[4]. They[5] formed[6] when the temperature of the earth[7] cooled[8]. Radioactive clocks[9] in rocks[10] began ticking[11].

1 Some rocks - can be directly observed.
2 found - an action within experience.
3 earth - can be directly observed.
4 million years old - length of time beyond anyone's experience.
5 They - pronoun referring to "some rocks" which can be directly observed.
6 formed - even though it refers to an action to which students can relate; in this case, forming a rock is a process which cannot be directly observed.
7 temperature of the earth - meaning earth's temperature can be directly observed or measured.
8 cooled - an action within experience.
9 Radioactive clocks - an analogue to aid students, but these "clocks" cannot be directly observed.
10 rocks - can be directly observed.
11 began ticking - an analogue to aid students, but is not an action within experience.

3. Count the total number of concepts (C + NC). Count the number of NC concepts.

4. Use this formula to determine the level of abstraction:

$$LOA = \frac{NC}{C + NC} \times 100$$