
Title	Assessing students' linkage ability
Author(s)	Lee Kam Wah
Source	<i>Teaching and Learning</i> , 13(2), 57-66
Published by	Institute of Education (Singapore)

This document may be used for private study or research purpose only. This document or any part of it may not be duplicated and/or distributed without permission of the copyright owner.
The Singapore Copyright Act applies to the use of this document.

Assessing Students' Linkage Ability

LEE KAM WAH

Introduction

Much research in the area of science education has attempted to find ways to enhance meaningful learning. What is meaningful learning? According to Ausubel's cognitive learning theory, meaningful learning involves relating new knowledge to knowledge previously learned via concepts (Ausubel, Novak and Hanesan, 1978). Ausubel distinguishes rote learning from meaningful learning as simple memorization of definitions and statements. The process of meaningful learning involves the linkage of concepts with specific meanings. Three areas of linkage are important in learning processes in science. These include:

- (1) Internal linkage in a cognitive structure (Novak, 1977; Champagne, Gunstone and Klopfer, 1985),
- (2) Activation of a particular part of cognitive structure for learning (Mayer, 1975),
- (3) External linkage between an existing cognitive structure and the new learning content (Novak, 1977; West, 1975).

The first type of linkage is concerned with the existing cognitive structure of how the learner's knowledge is effectively integrated or loosely related. The second type relates to the accuracy with which retrieval of a particular part of cognitive structure is achieved for use in learning a particular piece of new knowledge. The third type is concerned with the subsumption of concepts that enables the linking of the existing cognitive structure to new concepts or knowledge to be learned.

Various research techniques such as word association, concept mapping and interviewing have been used in the last decade for probing a learner's prior knowledge or cognitive structure. Some of these techniques, e.g. concept mapping have

been used and applied to a group/class or individual situation as a strategy to facilitate meaningful learning in science (Fensham, Garrard and West, 1981; Cliburn, 1990; Heinze-Fry and Novak, 1990; Wan, Lee, Goh and Chia, 1992; Lloyd and Peralta, 1992). Concept mapping is related to the first and second factors above that involve the linkage between known concepts and the retrieval of these concepts. If concept mapping involves some new concepts then the linkage is also conceptually related to the third factor.

The purpose of this article is to introduce two non-traditional measures as alternative forms of assessment to the traditional assessing techniques used in science classrooms, such as multiple choice questions, short answer, true/false and fill-in-the-blank questions, to measure student's linkage ability. Some findings of the earlier study (Lee, 1988) on the relationships between these two non-traditional measures and the traditional measures are briefly reported. The feasibility of using these two non-traditional measures will also be discussed.

Research Findings

These two non-traditional measures are called Word Association and Idea Association. The technique of Word Association is used to measure the relatedness between concepts. This is closely related to the first and second factors mentioned above. Idea Association is conceptually related to the second and third factors above and the technique used to measure them involves responses to external cues that are likely to be present in tasks that relate to a given knowledge domain.

The relationships between these two non-traditional measures and the traditional measures were investigated and reported in Australia (Lee, 1988). The investigation involved correlation analyses over four tests. The four tests were Word Association Test, Idea Association Test, Achievement Test (Multiple-Choice Questions) and Problem Solving Test. The latter two tests were traditional tests in terms of their formats. The topic involved in the tests was electrochemistry. Two groups of secondary chemistry students were involved. One group consisted of 214 Year 12 students from 6

schools and the other consisted of 60 Year 11 students from 4 schools (four of the above six schools). (Year 11 and Year 12 are equivalent to our Pre-U One and HSC.) The topic of electrochemistry was broken up into two parts that were taught in turns in Year 11 and Year 12. The tests were administered to both Year 11 and Year 12 students after they were taught either the first or second part of the topic. The content knowledge required for the four tests based on the first part of electrochemistry was covered in Year 11. The Pearson correlations among the four tests for the Year 12 group were computed and are shown in Table 1.

Table 1. Year 12 Data

	Problem Solving	Achievement	Word Association	Idea Association
Problem Solving	1.0	0.38	0.24*	0.48*
Achievement		1.0	0.08	0.41
Word Association			1.0	0.09
Idea Association				1.0

Part-correlation analysis was used to find the correlations among the tests taken by the Year 11 students, after considering the effect of prior knowledge possessed before they were taught the topic. The effect of prior knowledge was taken into account because it was the first time that Year 11 students were learning this topic, and naturally their prior knowledge was influential to their learning process. The results are shown in Table 2.

Table 2. Year 11 Data

	Word Association	Idea Association
Problem Solving	0.59*	0.42*
Achievement	0.11	0.25

The results shown above indicate that the Year 11 data agree with the Year 12 data in terms of correlation between the two different types of measure, namely the traditional and non-traditional assessment methods. The problem solving test correlates significantly (see figures marked with asterisks in the above tables) with both the Word Association and Idea Association test for both Year 11 and Year 12.

These results imply that the two non-traditional measures can be used as alternative means to assessing learning by a traditional test. They can also provide insight into the conceptual structure students have and into how students go about linking what they know to the more complex learning tasks such as problem solving that they are going to learn. Teachers would then be better able to identify the students' weaknesses in understanding the concepts and perhaps be able to enhance that understanding. The rest of this article will discuss on the preparation of tests, time required to carry out the tests and the scoring of the tests.

Design And Administration Of Word Association Test And Idea Association Test

Word Association Test

The test consists of two tasks: (a) word association and (b) generating propositions. These, as used by Gunstone (1980), were adopted to measure the concept relatedness among different concepts. The preparation of this kind of test is technical but reasonably easy once the important concepts of a topic are identified. An example with instructions is shown in Appendix 1. One just needs to choose 4 to 6 important concepts within the topic. The same concept, e.g. reaction, is printed repeatedly in the first column of the page. There are two other columns of spaces arranged side-by-side with the first column of words. In the first task, students are asked to write in column 2, from their science knowledge (or any specific science domain such as chemistry) a word that come to their mind first each time they see the cue word in column 1. The teacher controls the pace of the whole test by announcing when the students start and end the task for each concept. One minute is allocated for each concept to be related. This task continues until they finish all the concepts.

Once the first task is completed, the second task of generating propositions by writing a sentence or a phrase in column 3 begins. The proposition connects the words from column 1 to column 2 to form meanings. The second task is used to validate the responses in column 2, to see if the responses are relevant within the science domain. The time required for the second task is flexible and up to the teacher's discretion. It is suggested that 5 minutes be allocated for writing the sentences or phrases for each concept (i.e. for each page) in column 3.

The sequence of the 4 to 6 concepts in separate sheets was randomly arranged so that the recall and chaining effects can be reduced.

Where scoring is concerned, one just needs to count the same associated words between two concepts and then calculate the ratio of the same associated words to the maximum words association. The Garstof and Houstons' formula on relatedness coefficient (1963) for measuring the relatedness of two words is employed. The formula for the related coefficient of two words is expressed as the ratio of the obtained overlap to the maximum possible overlap. Teachers can use the associated words being validated by sentences or phrases shown in column 3 to work out the concept relatedness ratios of different pairs of concepts. Calculators would be very useful in doing these computations. An example is shown below to illustrate how concept relatedness ratio between two concepts can be calculated.

Example:

Some words associated with the two concepts 'redox reaction' and 'ionic equation' are shown: (These associated words are presumably being validated.)

*redox reaction**

electrons*

oxidation

change

chemicals

ions*

ionic equation

ions*

redox reaction*

electrons*

colour

Common words (marked with asterisks) associated with both stimulus words i.e. redox reaction and ionic equation are: *electrons, ions, redox reaction*.

Therefore number of overlapping words associated = 3

Maximum possible overlap = total words associated with 'redox reaction' + stimulus word = 5 + 1 = 6 words

Relatedness coefficient for the two concepts i.e. redox reaction and ionic equation = $3/6 = 0.5$

By using the above formula, a number of relatedness coefficients for the test consisting of few concepts can be computed. e.g. Six relatedness coefficients can be obtained for a set of four concepts. The sum of the relatedness coefficients of different pairs of concepts is the score for this test.

Idea Association Test

The format of the Idea Association Test is different from the Word Association Test. The preparation of the test depends on the use of key words and the problem stem of typical tasks. For each key word or problem stem, enough space is given for students to list all the possible associations. The associative responses could be ideas, concepts, words, diagrams, symbols or equations. For example, if a problem statement is given as follows:

"A yellow colour is produced when a solution of potassium iodide is left exposed to the atmosphere. Is this reaction a redox reaction?"

A few key words such as "atmosphere", "reaction", and "redox reaction" or sometimes the problem stem, can be considered to be used for this test. The key words and the problem stems have to be arranged randomly so that one can tap a wider range of associations instead of only one sort of association for one problem. The instructions and some parts of the test based on the above example are shown in Appendix 2.

The time required for the test is flexible. One minute can be allocated for each key word and about 3 minutes for a problem stem.

The teacher controls the students' pace of work for the whole test. She or he announces the key words or problem stem and time the students have for each item in making their written responses. To score the test, the teacher has to count the number of associations relevant to the solution of the task including words, diagrams, symbols, etc. This would be easier if the teacher had a list of relevant information as guidelines for scoring. The total number of associations retrieved by the cues from the same problem statement is considered as part of cognitive structure that had been provoked and the retrieved association hence is likely to be available for use in solving the problems.

Conclusion

These non-traditional measures, especially the word association, are not new to many science researchers but they are new to most teachers in the current school assessment systems. They are open-ended tests which assess students' linking ability and also their accuracy in retrieving the relevant knowledge. These tests offer an alternative to the 'spoon-fed' and 'drilled' types of assessment. They can also be used in class as a form of activity for improving students' linkage ability which is important for meaningful learning. The earlier study has statistically proven that these two non-traditional measures assess learning performance as well as the traditional methods. Apart from providing the numerical scores for the learning performance, the two non-traditional tests also provide teachers with useful qualitative evidence of how students are proceeding with their learning and understanding of concepts. The technical procedures of setting, carrying out and scoring the tests are reasonably easy to handle. With the information given above, it is suggested that word association and idea association be used as part of science instruction and assessment in schools.

References

- Ausubel, D.P., Novak, J.D., and Hanesan, H. (1978) *Educational Psychology: A Cognitive View* (2nd Ed.). New York: Holt, Rinehart and Winston.

- Champagne, A.B. Gunstone, R.F., and Klopfer, L.E. (1985) Effective Changes in Cognitive Structures among Physics Students. In West, L.H.T. and Pines, A.L. (Eds.), *Cognitive Structure and Conceptual Change*. Orlando, Florida: Academic Press.
- Cliburn, J.W. (1990) Concept Maps to Promote Meaningful Learning. *Journal of College Science Teaching*, 20: 212-217.
- Fensham, P.J., Garrard, J.E., and West, L.H.T. (1981) The Use of Cognitive Mapping in Teaching and Learning Strategies. *Research in Science Education*, 11: 121-129.
- Garskof, B.E., and Houston, J.P. (1963) Measurement of Verbal Relatedness: An Idiographic Approach. *Psychological review*, 70(3): 277-288.
- Gunstone, R.F. (1980) Word Association and the Description of Cognitive Structure. *Research in Science Education*, 10: 45-53.
- Heinze-Fry, J.A. and Novak, J.D. (1990) Concept Mapping Brings Long-Term Movement Towards Meaningful Learning. *Science Education*, 74(4): 461-472.
- Lee, K.W. (1988) Two Non-traditional Measures of Chemistry Learning: Word Association and Idea Association." *Research in Science Education*, 18: 169-176.
- Lloyd, J., and Paralta, C. (1992) An Examination of the Use of Concept Mapping in Primary Science in Singapore. Proceedings of the sixth annual conference of the Educational Research Association Singapore. *Curriculum research and practice: Cauldron or crucible?* pp. 147-154.
- Mayer, R.E. (1975) Information Processing Variables in Learning to Solve Problems. *Review of Educational Research*, 45(4): 525-541.
- Novak, J.D. (1977) *A Theory of Education*. Ithaca and London: Cornell University Press.
- Wan, Y.K., Lee, K.W., Goh, N.K., and Chia, L.S. (1992) Concept Mapping in Science Instruction: Proceedings of Teaching in Science Seminar. *Enhancing Teaching Effectiveness*. pp. 22-27.
- West, L.H.T. (1975) *The Organizing Role of Prior Knowledge and Advance Organizers in Chemical Learning*. Unpublished Ph.D. thesis, Monash University, Victoria, Australia.

Appendix 1

Word Association Test

ON EACH PAGE YOU WILL FIND THE SAME WORD **WRITTEN** MANY TIMES.

FROM **YOUR** KNOWLEDGE OF SCIENCE, WRITE DOWN IN COLUMN 2 **ALL THE** WORDS THAT COME TO YOUR **MIND** WHEN YOU THINK OF THE WORD IN COLUMN 1.

DO NOT USE COLUMN 3 **AT THIS** STAGE. YOUR TEACHER WILL TELL YOU WHAT TO DO **WITH** COLUMN 3 **LATER**.

DO NOT WORRY ABOUT SPELLING AND **WRITE** AS MANY WORDS AS YOU CAN.

YOU WILL BE GIVEN ABOUT 1 MINUTE FOR EACH PAGE OF **THIS** TASK.

Example:

1.	reaction	_____	_____
2.	reaction	_____	_____
3.	reaction	_____	_____
4.	reaction	_____	_____
5.	reaction	_____	_____
6.	reaction	_____	_____
7.	reaction	_____	_____
8.	reaction	_____	_____
9.	reaction	_____	_____
10.	reaction	_____	_____
11.	reaction	_____	_____
12.	reaction	_____	_____
13.	reaction	_____	_____

Appendix 2

Idea Association Test

IN **THIS** TEST THERE ARE A NUMBER OF SCIENCE WORDS AND IDEAS.

FROM YOUR KNOWLEDGE OF SCIENCE, WRITE AS MANY OTHER PHRASES OR SENTENCES INVOLVING THESE WORDS OR IDEAS AS YOU CAN. ALSO DRAW ANY DIAGRAMS THAT COME TO **MIND** WHEN YOU THINK OF THESE WORDS OR IDEAS.

THERE ARE MANY RIGHT ANSWERS; DO NOT WORRY ABOUT SPELLING.

YOU **WILL** BE GIVEN 1 MINUTE FOR EACH OF THE ITEMS.

1. *atmosphere*

2. *redox reaction*
