# USING CONCEPT MAPS TO ASSESS THE SCIENCE UNDERSTANDING AND LANGUAGE PRODUCTION OF ENGLISH LANGUAGE LEARNERS

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**Abstract:** This paper describes the use of concept maps to assess the understanding of science concepts and science language production of elementary students who are English languages learners (ELL). The assessment of science content understanding in ELL students is particularly challenging because it is difficult to determine whether students' performance reflects their understanding of the concepts or their language proficiency. Concept maps allow students to demonstrate what they have learned in their primary or second language or both, in a task where the linguistic demands are minimized. A method is described which evaluates 400, grades 2-5 ELL student's performance in four categories: (1) number of propositions, (2) scientific accuracy, (3) depth of explanation and (4) science vocabulary. The results show that concept maps can be used to assess growth in ELL understanding of science concepts.

## 1 Introduction

The availability of appropriate science assessments is an issue facing many educators as they make steps toward implementing inquiry-based instructional approaches in the elementary classroom. It is difficult to measure student learning in open-ended inquiry learning environments. Traditional closed-ended methods of assessment, such as multiple choice tests, do not capture students' ability to develop and carry out independent investigations nor do they measure the development of student conceptual understanding (Escalada & Zollman 1997, Ruiz-Primo & Shavelson , 1996b). Ruiz-Primo & Shavelson proposed the use of concept maps as alternatives to the use of closed-end assessments. Concept maps are grounded in a psychological theory which focuses on individuals and how they integrate new learning into existing conceptual frameworks by making explicit, conscious connections between concepts as a way to integrate information into memory (Ausubel 1968; Ausubel, Novak, & Hanesian 1978; Novak & Gowin 1984; In science instruction, the concept map activity (CM) focuses on students' ability to use science language to represent their understanding of science concepts. The basic form of a concept map consists of words or phrases that are connected together with linking words or phrases to form complete thoughts called 'propositions' (Novak & Gowin, 1984; Ruiz-Primo & Shavelson, 1996a; Stoddart, Abrams, Gasper, & Canaday, 2000). The validity of the CM activity as a science assessment has been established through correlation with other science content measures and external science standards such as text books, science web-sites, and research scientists (Stoddart et al, 2000). Student scores on concept maps have been shown to be correlated with scores on conventional assessments, including teacher developed tests and national standardized tests (Farrokh & Krause 1996; Liu & Hinchey 1993; 1996; Rice, Ryan & Samson, 1998; Wilson 1993).

The assessment of science content learning is made even more completed by the increasing number of U.S. students who do not speak English as a first language. The assessment of content understanding in English Language Learners (ELL) is particularly challenging because it is difficult to determine whether students fail to perform because they have not mastered the concepts, or because they simply lack the linguistic resources to demonstrate what they have learned (Met 1994). An appropriate assessment allows students to demonstrate what they have learned; what they do know and can do, not what they do not know and cannot do. Concept maps allow students to demonstrate what they have learned in their primary language in a task where the linguistic demands are minimized.

This paper proposes that concept mapping is a particularly useful assessment in measuring ELL students' science and language learning in an inquiry science learning environment. The linguistic task demands can be tailored to students' level of language proficiency. The content demands can be tailored to the specific content that an individual student or class pursues. In addition, concept maps can be used to measure both science understanding and the development of academic science vocabulary. Science vocabulary plays an important role in learning science because it involves a process of developing relationships among ideas, terms and meanings (Fradd and Larrinaga McGee 1994, Lemke 1990). Concept maps focus on these relationships. This paper presents a method to use concept maps as assessment of science and language learning for ELL students.

## *2* Concept Map Activity

The CM activity in this study is incorporated into classroom instruction and designed to assess the content students are currently learning. The classroom teacher and/or researcher identify the key concepts within a unit of science that will be taught. Using this overall list of concepts, they chose three 'superordinate' concepts—those which would elicit from students the broadest possible range of related concepts. For example, for a unit on 'Habitats' a teacher might choose; habitat, living, nonliving rather than soil, grass, mouse. These three superordinate concepts are used as prompt words for students when they began the concept map activity. Things to keep in mind for choosing the three overarching concepts include: (1) they should be central concepts to the unit topic; (2) they should be broad enough to help initiate students' brainstorming about other concept words; (3) if the concept map activity is being used as pre and post assessment, the overarching concepts should be words that are meaningful to students even before instruction. Students are given a list of the three overarching concepts, and four to seven additional spaces (depending on their grade leveli) to generate their own concept words that relate to the topic. Once students complete their list of concepts, they are instructed to use these words to build a concept map (see Table 1 below).

Nombre/Name:____________________________ Fecha/Date_____________________________

Maestra/Teacher:___________________________________

**Este trabajo tiene dos partes.**

1) Escoja 4 palabras sobre **los cambios que las plantas pasan durante su desarrollo** que usted crea son conceptos importantes. Pongalas en la lista abajo. Tendra un total de 7 conceptos.

2) Use estos 7 conceptos para hacer un mapa de conceptos que muestre lo que sabe de **los cambios que las plantas pasan durante su desarrollo**.

**This job has two parts**.

1) Choose 4 words about **the changes that plants go through** that you think are important concepts. Add them to the list below. You will have a total of 7 concepts.

2) Use these 7 concepts to make a concept map to show what you know about **the changes that plants go through**.

**1) Plantas**
**Plants**

2) Cambios
**Changes**

**3) Ciclos**
**Cycles**

**4) ____________________**

**5) ____________________**

**5)___________________**

**7)____________________**

**Table 1:** Concept Map Protocol

The concept map administration protocol consists of three parts. In the first step, introduction to concept mapping, a trained administrator provides direct instruction and modeling on how to make a concept map, with students participating verbally and constructing a group concept map. In the second step, students are provided with the three overarching concepts, and asked to generate a word list of additional concept words that are related to the main topic. In the third step, students produce their own concept maps using the word bank they had just generated. Introduction of the activity is designed to take less than 25 minutes. Instruction is conducted in students' primary language. Students are not expected to construct a map on their own.

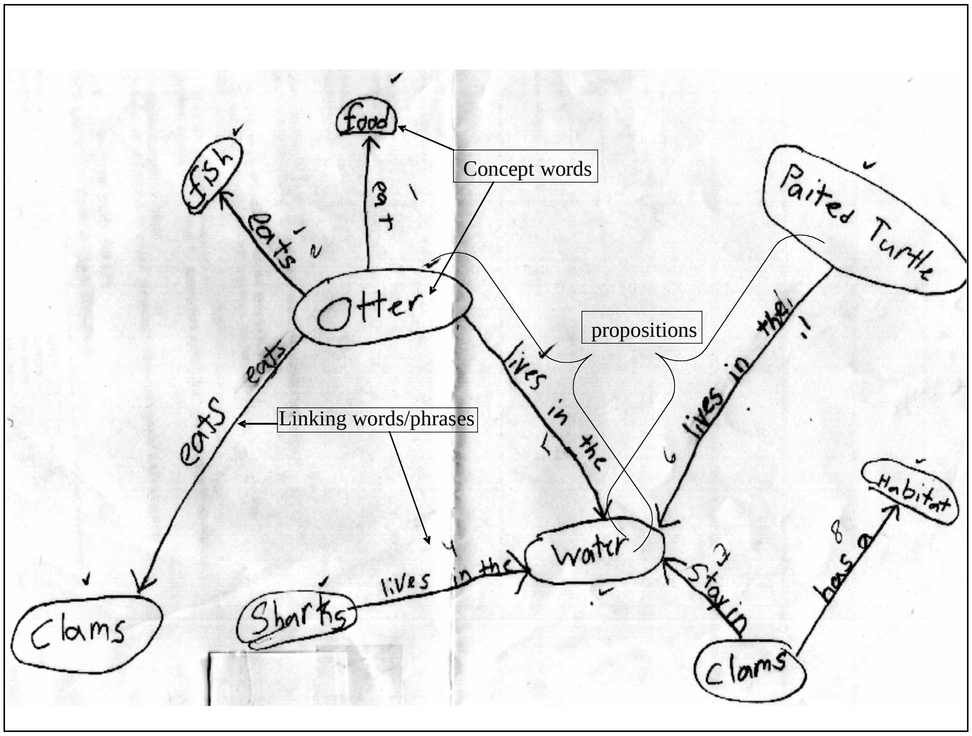


**Figure 1:** Concept map produced by a third grade ELL student

## 3 Scoring and Results

Criteria were developed to assess ELL student on science content understanding and the use of science language. The concept map protocol was administered to 200 $2^{nd}$ through $5^{th}$ grade ELL students attending a four week science summer school program for children of migrant agricultural workers from Mexico. The students had a range of language proficiency but most were beginning and intermediate English language speakers. The concept map activity was presented by the classroom teacher and researcher using the standard protocol. Concept maps were produced at the beginning and end of a four week science instructional unit which taught earth science through a garden curriculum. The concept maps were scored by two trained researchers. Inter-rater reliability was .80.

### 3.1 *Science Content Understanding*

The concept maps are scored on three science content criteria: (1) overall number of propositions, (2) scientific accuracy and (3) depth of explanation.

#### 3.1.1 Number of Propositions

The open-ended nature of the concept mapping task allows students to produce as many or as few propositions as they see fit to express their understanding. Looking at the overall number of propositions on the pre- and post-assessments provides a broad overview of student performance. As Figure 2 shows,, the participating students significantly increased in the number of propositions per map, from an average of 5.98 to 7.77 [F=3.214, df (2,99), p<.05]. This result indicates that students were able to write more propositions on the main topic at the end of the unit as compared to the beginning. It is a broad overview; it does not take into account familiarity with the task or scientific accuracy of the propositions.

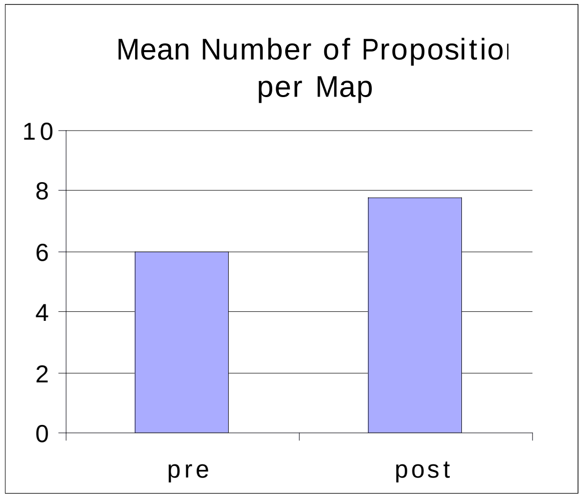


**Figure 2: Mean Number of Propositions in pre- and post-assessments**

### **3.1.2** Accuracy

Student concept maps were scored on four levels of Accuracy: 1. scientific accuracy, 2. common knowledge, 3.) inaccurate statements, and affective statements. See Table 2.

1. Scientific accuracy is defined as correct statements about scientific content, with 'scientific' meaning content which is typically learned in grade school science curricula, content of a particular field of science, and content learned from the scientific process. The latter includes specific observations such as exact measurements.

2. Common knowledge is defined as non-scientific, everyday knowledge. This includes topics such as playing, and material needs of people.

3. Inaccurate statements are those that are commonly accepted by scientists to be incorrect, at the level of complexity appropriate to grade school science curricula. Inaccurate statements comprise less than 10% of the overall group of maps. This is most likely due to the open-ended nature of concept mapping, where students are asked to report what they do know, rather than address specific content areas that may be beyond their expertise.

4. Affective statements are defined as those that express emotions, feelings or personal thoughts.

| Category | Score | Example |
|---|---|---|
| *Accuracy* | Scientifically Accurate | Roots need water |
| | Common Knowledge | Kids play with dogs |
| | Inaccurate | Dinosaurs eat gorillas |
| | Affective | I love flowers |

**Table 2:** Categories of scientific accuracy

To take into account the change in overall number of propositions, scientific accuracy is analyzed as the ratio of these propositions to the overall number of propositions. Pre- and post-assessment showed that school students significantly increased the proportion of scientifically accurate propositions in their maps from 13.9% to 52.5% [F=6.16, df(1,100), p<.05]. See Figure 3.

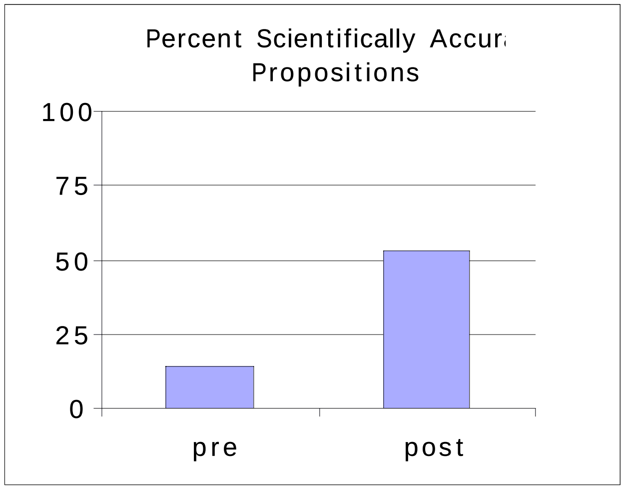


**Figure 3:** Percent of scientifically accuracy propositions in pre- and post-assessments

### 3.1.3 Depth of Explanation

The Depth of Explanation criterion differentiates between: 1. factual statements; 2. extended factual statements; 3. higher order explanations. See Table 3.

1. Factual statements are defined as subject-verb-object propositions that provide basic descriptions or informational statements, and do not attempt to provide explanations concerning function or purpose. They often answer 'what' questions.

2. Extended factual statements contain additional elaboration beyond subject-verb-object, such as additional clauses. They provide basic descriptions or informational statements, and do not attempt to provide explanations concerning function or purpose. They often answer 'what' questions.

3. Higher-order explanations are defined as propositions that describe function or purpose. They often address 'how' or 'why' questions. The researchers have empirically found in other studies that higher-order explanations comprise more elaborate grammatical structures than subject-verb-object, and are therefore not divided into two groups as the basic descriptions.

| | | |
|---|---|---|
| *Depth of Explanation* | Factual | Plants need sunlight |
| | Extended factual | Plants need sunlight in order to grow |
| | Higher-order explanation (answers 'how' or 'why') | Plants use sunlight and carbon dioxide to produce their own food |

**Table 3:** Depth of explanation categories

To take into account the change in overall number of propositions, depth of explanation are analyzed as the ratio of both extended factual and higher order explanation to the overall number of propositions. There was no significant change in the 'depth of explanation' score over the course of summer school. These results are not surprising, given the short period of instruction being assessed and the age of the students participating in the study. More complex levels of understanding develop over an extended period of time. In addition, younger students offer less elaborated explanations than older students. The students, however, did make significant gains in scientific accuracy, which is a precursor to developing higher order understandings.

### *3.2 Science Language*

The vocabulary component is used to evaluate students' use of language in the concept maps. The focus is primarily on students' ability to incorporate science vocabulary in their explanations of science concepts. Science language is classified as: 1. common or 2. specialized. See Table 4.

1. Common refers to science words that are developmentally appropriate for both social and academic discourse by students, for example, 'tree,' 'sun,' 'plants,' and 'dirt'.

2. Specialized refers to science terms that are specific to an academic science discipline. This category of science terms contains: (1) terminology specific to a cognitive, academic setting, that are not common in social discourse, such as 'thermal energy,' 'cytoplasm,' and 'mitochondria,' and (2) science words internalized from an academic setting, such as 'Fahrenheit,' 'cells,' and 'atoms.'

| **Category** | **Examples** | | | |
|---|---|---|---|---|
| | **Common** | | **Specialized** | |
| Chemistry | Hot<br>salt<br>water | Caliente<br>sal<br>agua | oxygen<br>convection<br>atoms | oxígeno<br>convección<br>átomos |
| Physics | Light<br>color<br>sound | Luz<br>color<br>sonido | gravity<br>thermal energy<br>force | gravedad<br>energía termica<br>fuerza |
| Physical Geography | Rain<br>moon<br>mountain | Lluvia<br>luna<br>montaña | solar<br>tide<br>fossil | solar<br>marea<br>fósil |

**Table 4:** Earth Science Vocabulary Examples in English and Spanish

As Figure 4 shows, students' use of both common and specialized Earth Science vocabulary significantly increased over the course of summer school [common: $F=5.28$, $df(1,104)$, $p<.05$; specialized: $F=8.83$, $df(1,104)$, $p<.005$].

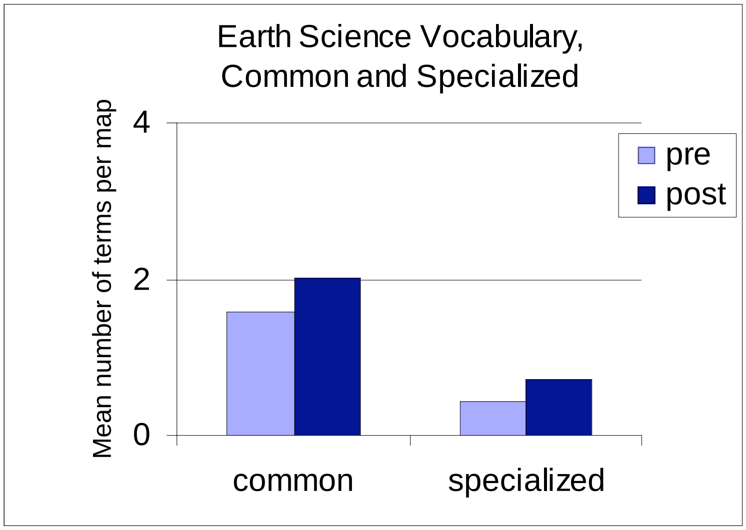


**Figure 4:** Science Language

## 4 Summary

This paper described and tested a concept map methodology to measure the development of ELL students' science understanding over the course of a four-week science inquiry summer school. The concept mapping technique was selected because: it is curriculum-sensitive; it focuses on what the students know, rather than what they don't know;

it does not require students decode or to produce extensive text; it can be completed in either English or Spanish or a combination of both languages. In addition, concept maps can be used to measure both science content and the use of science language. The results show that student learning can be reliably assessed using this method. The data from the concept maps demonstrate that there was a significant increase in students' science understanding over summer school. The proportion of scientifically accurate concepts that the students produced increased from 14% to 53% in the pre and post assessments. Students also showed significant growth in their scientific vocabulary. They increased in their ability to use both common scientific terms and specialized scientific terms in life and earth sciences. The increase in both accuracy of content understanding and the use of scientific vocabulary suggests that students were able to learn both science content and the academic language of science.

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