Faculty Publications

2014

Unpacking the Language of STEM for English Language Learners

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For *Learning Abstracts*

Unpacking the language of STEM for English language learners
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This article is a follow-up to a workshop we presented at STEMTech 2013 entitled "Unpacking the language of STEM for English language learners." We chose this topic because, in our roles as co-directors of the ESL STEM Success Grant (a 5 year national professional development grant from the Office of English Language Acquisition, U.S. Department of Education), we have been exploring ways that teachers across the grade levels can rise to the challenge of more effectively teaching English language learners (ELLs) in the STEM disciplines. (STEM, of course, stands for Science, Technology, Engineering, and Mathematics.) When teachers embed their understandings of the language demands of STEM into their teaching of ELLs, those students are better able to learn, and comfortably use, the language of the STEM fields. This provides them with greater career options while at the same time addressing a great national need.

As readers of *Learning Abstracts* already know, English language learners at community colleges represent a wide variety of home languages and prior educational experiences. The percentage of children and youth who speak a language other than English at home in the US is 18% in large metropolitan areas (Aud, et al, 2012). Some of them attended ESL or bilingual programs whereas others did not. Some youth are "Generation 1.5" students who arrived in the US as teenagers (Harklau, Losey, & Siegal, 1999). Students with a wide range of linguistic, cultural and educational backgrounds have been referred to as the "New Mainstream" because all educators need to address their backgrounds. The trend in K-12 contexts is for all teachers to receive training in teaching linguistically diverse children (Clewell, de Cohen, & Murray, 2007). In post-secondary contexts, much attention has been paid to linguistic diversity in writing programs (Roberge, Siegal, & Harklau, 2009), but less attention has been focused on how to effectively address linguistic diversity in STEM classrooms in community colleges.

From conversations with participants in our 2013 workshop and in related reading, we can see that community college instructors are interested in taking up the challenge of assisting linguistically diverse students in content reading and

writing. However, teacher understanding of the language demands of STEM is necessary to promote learning for diverse students in STEM classrooms.

The language of STEM is not one-size-fits-all by any means. A recent look at the structure of STEM academic language in *Review of Educational Research* (DiCerbo, Anstrom, Baker & Rivera, 2014) confirms the existence of a wide variety of text structures and reading/writing demands in the STEM subject areas.

In the domain of science in particular, as science courses become more difficult, both the content and language of science become dramatically more difficult. Mastering the information in the texts can produce obstacles for ELLs and deter them from even considering advanced coursework which could allow them to fulfill their talents and interests in the STEM fields.

The difficulty with the language of science is not from vocabulary alone, but from sentence structures, references within and between sentences, and larger discourse patterns. Language analysis can be informed by systemic functional linguistics, an approach which analyzes oral and written texts to discover the structures through which they create meaning, according to their purposes (Schleppegrell, 2005; Fang & Schleppegrell, 2010). Systemic functional linguistics (also called *functional linguistics*, *SFL*, or *functional language analysis*) is showing promising results in assisting ELLs in better accessing and using academic language (e.g. DiCerbo, Anstrom, Baker & Rivera, 2014; Nagle & Macdonald, 2011) although the evidence is still preliminary.

This article briefly describes three characteristics of the English language that abound in science writing in particular. We will move from the smallest unit of the three to the largest. Morpheme study, the first, looks at units of meaning within words, called morphemes (for example, "books" consists of two morphemes, "book" and a plural suffix "-s"), which can help students recognize and understand unknown words by looking for parts they can figure out. Passive voice, the second, occurs at the sentence level and is a very common sentence structure in academic writing. Students need to learn to recognize the agent of sentences written in passive voice. They also need to be able to write up procedures and lab reports in passive voice, not only in short sentences using "is," but in longer, complex sentences in a variety of tenses. Nominalizations, the third, consist of a linguistic transformation to changes verbs to nouns to facilitate connections between or among several sentences. They abound in science and

other technical writing. Understanding these three features will help instructors tackle complex texts with their students in order to remove obstacles to understanding and allow for greater success in both advanced reading and writing.   `          `

MORPHEMES
In the language of science, the importance of recognizing many roots, prefixes, and suffixes cannot be overstated. Learning science morphemes can greatly assist students in reading science texts.

ELLs from Latin-based languages have a decided potential advantage in the number of cognates between their languages and English, in particular in science vocabulary, because so much science vocabulary in English derives from Greek and Latin root morphemes.

English language learners benefit from explicitly-taught morpheme instruction (Kieffer & Lesaux, 2008) but may learn only as much as the teacher knows, and this is often limited (Kieffer & Lesaux, 2012).

Classroom Applications

When morpheme study is introduced early in a content reading or science course, there is adequate time for students to learn to recognize them in the units of study.

Here are some common morphemes used across several science disciplines. These roots combine with other roots and affixes to form many compound words.

hydro
geo
hyper/hypo
scope

Students can brainstorm words that use these roots, and keep track of them in reading. A teacher can pull out several important roots at the beginning of a unit because they may appear in numerous word forms.

Key affixes (prefixes, suffixes, or roots) should also be taught explicitly:

Examples: -ation   verb -- > noun
             -ize   noun   → verb
             -ify   noun   -→ verb
             de-   undoing a process

Once they are discussed, students will notice them as they speak and read, and many new words will become comprehensible. As an example of the generative nature of these affixes, in our own ESL STEM Success Grant, we try to put more emphasis on the STEM subjects in our ESL endorsement coursework, and to describe this process, we have coined the word "STEMifying" the curriculum. At first our new word sounded funny, but we've used the term for 3 years now, and it continues to fit our needs!

Students also benefit from knowing common singular and plural forms derived from Latin that are used in so many science terms, both technical and general. These words do not follow the standard English plurals pattern of adding the morpheme "s" or "es" at the end of a word, but follow the Latin system instead. Knowing the Latin plural endings allows a reader to know whether a scientific word is singular or plural, and this is very useful.

We are highlighting five especially productive singular-plural pairs here:

Latin singular/plural morpheme	example
-is/-es	neurosis/neuroses
-us/-i	stimulus/stimuli
-ex/ix/-ices	vertex/vertices
-a/-ae	nebula/nebulae
-on/a	criterion/criteria

Teachers can scaffold ELLs to recognize and write these two forms through a t-chart such as the one below, which provides one form of the Latin word and asks the students to provide the other form.

T CHART FOR SELECTED SINGULAR AND PLURAL FORMS OF LATIN-BASED WORDS
Singular   plural

antenna   _____

_____   phenomena

crisis   _____

After practicing these forms, teachers can ask students to find more examples from their science text or other readings as the course continues. If the teacher has his or her own classroom, these singular-plural pairs can be put up on a chart on the wall.

To stimulate students to notice morphemes, we enjoy a game in which teams vie to create the longest list of words containing the target morpheme within a fixed number of minutes.   The lists are compared, and the team with the most unique number of words wins the round (Lems, Miller & Soro, 2010). When teachers play against the student teams, they often find that the students leave them in the dust!

PASSIVES

Scientific and academic writing makes use of many passive sentences, and it is in fact one of the hallmarks of academic language. People do not speak in passive voice in conversational settings, but passive voice is heavily employed in formal writing. The preponderance of passive voice in science texts makes it imperative for students to be able to rapidly and accurately construct meaning from texts which use passive, yet this takes training and practice.

A sentence in the passive voice "flips" the position of the object of a sentence into the subject position, often omitting the former subject or changing it into a "by-phrase" at the end of the sentence. Here is a simple example:

<u>Melted rock and soil</u> form <u>the earth's mantle</u>.
Subject   object
To form the passive, we flip the positions of the subject and object.

<u>The earth's mantle</u> is formed <u>by melted rock and soil</u>.
New subject   by-phrase with the former subject

It's pretty straightforward to move the positions in sentences such as the one above. In fact, passive voice is one of the grammatical items nearly all English

language learners study if they have advanced academic training in English as a Second language. However, as community college instructors surely know, the New Mainstream consists of students with diverse educational experiences, so many students do not have this training. In addition, it is considerably more difficult for students whose first languages do not contain the passive voice!

The other tricky thing about passive voice is that a sentence with passive voice doesn't necessarily have a by-phrase, and when it doesn't, the agent or actor can be hard to discern. For example:

The earth was formed several billion years ago. (no by-phrase)
It is not clear from the sentence what formed the earth several billion years ago.

Sometimes, instead of a by-phrase, we might see a different connector:

Tornadoes are formed through a process of warming air and moisture.
A process of warming air and moisture formed the tornadoes, but the by-phrase is replaced by the word "through."

Classroom applications

In ESL classes, students spend time turning passive to active voice and vice versa. For academic reading in the content areas, one good way to practice academic discourse structures is through the use of sentence frames (Arechiga, 2013). Sentence frames, or partially completed sentences, have been part of grammar-based ESL classrooms and textbooks for years, but they can be used in a more discipline-specific way in content-based ESL classrooms. For example, passive voice sentence structures can be practiced with a frame such as the one below on a variety of general scientific topics:

Frame: _____ is _____ by _____.

Examples:	Weather	is impacted	by rising air currents.
	Ice	is melted	by heat.

To make this work, the teacher should have several additional examples prepared in advance that are relevant to the current readings or topic; as the tenses become more advanced, preparation is even more important.

After a frame has been introduced, other sentences can be generated using the frame over the course of the teaching unit.

Another useful way to practice understanding the passive is by changing passive sentences into active voice, in order to better understand the actor, or agent, of the action.   For example, we can encounter a sentence such as this one in many physics textbooks: "the motion of an object is usually described with respect to something else…" It is useful for students to be able to understand that in its active form, it says, "People usually describe the motion of an object with respect to something else…."

For this practice, too, the teacher should have chosen several sentences from the target reading in advance, and he or she can provide a careful think-aloud of how the action in the sentence is performed. Over time, these transformations can become automatic and unconscious to a reader and form part of his or her increased reading comprehension.

NOMINALIZATIONS

Science writing is dense in both concepts and language. The economical nature of science writing can make reading a textbook a daunting task. Complex concepts or procedures can be defined or summarized by nominalizing them in the sentence or paragraph that follows. Nominalizations often put the subjects of sentences into a "zig zag" pattern (Nagle & MacDonald, 2011) in which the subject of the second sentence "points back" to the previous sentence. Descriptions of concepts and processes in the first sentence become "nominalized" (turned into a noun or noun phrase) in the following sentence. Here are two examples:

Example: When air molecules heat up, they collide. This collision causes….

"This collision" refers to the process described in the previous sentence, which serves as the de facto definition of "collision" in this context. An ELL reader needs to know that the entire first sentence can be encompassed in the definition of "this collision" in the following sentence.

Example: This was at the time that many of the secrets of life were revealed. The trigger for these revelations was the discovery of the structure of DNA…

"These revelations" in the second sentences points back to the whole first sentence. The revelations were the many "secrets of life" revealed at that time. To understand the meaning of "revelations," we must summarize and scramble the previous sentence. This is an advanced reading task which stymies many native speakers, but is even harder for ELLs because keeping the meanings of sentences in working memory is harder when reading and language acquisition are still developing (Swanson, Orozco, Lussier, Gerber, & Guzmán-Orth, 2011).

Classroom applications:

We practice identifying the meanings of nominalizations by the tried and true process of circling parts of texts and drawing lines between them. In the case of science writing, this is much more effective than having students look up a concept in the dictionary (or by right clicking on it for synonyms, or using google translator). Marking a text this way helps students see the connections between sentences and build reading comprehension beyond vocabulary learning.

A good way to practice is to type up a sample passage from the class science text (best to use your real textbook, in a unit you are really studying), double spaced, and give one copy per student (Stegemoller & Miller, 2012). Have the students circle the item in the first sentence and draw a line to its nominalized form in the next sentence (or vice versa). The first few times, you'll need to point out the nominalization first, and then "backload" to the previous sentences or sentences to find the description, definition, or process. As texts get harder, the former may be several sentences away, or even in a previous paragraph. However, good editors insure that the nominalization is not too far from its antecedent, no matter what the subject area!

Learning to understand and use the academic register of the STEM subjects is a goal that cannot be realized in a short time frame, but it is a very rewarding long term goal. Best of all, it is an achievable goal, both for ELLs and for their teachers alike. The reward of this effort is an "open sesame" into a portal which opens a dazzling, vast world of the STEM fields. May you, and your students, enjoy learning the "magic words" for that portal, and the journey into the glittering cave of wonders that they make possible!

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