Science and Language Special Issue: Challenges in Preparing Preservice Teachers for Teaching Science as a Second Language

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Abstract

Science is a subject steeped in specialized vocabulary and elementary preservice teachers may find themselves less than comfortable with that vocabulary. Couple this with their long documented fear of the subject and we have teachers who enter their first classrooms unsure of themselves and the content and thus, less able to prepare their own students. Common challenges these new teachers face include the specialized vocabulary of science, the speed at which words are introduced as well as the sheer vocabulary load of the subject, and the difficulty of English language learners attempting to learn science. This article suggests vocabulary strategies for each challenge and advocates for the incorporation of modified Total Physical Response methods when teaching science content. These suggestions will help science educators relieve the stress preservice teachers find when attempting to learn the language of science.

Keywords: science education, science vocabulary, vocabulary strategies, English language learners

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Introduction

Science is a subject steeped in specialized vocabulary, and because of this we may think of it as a language all its own (Brown & Ryoo, 2008; Lee, 2002, Michaels, Shouse, & Schweingruber, 2008). Preservice teachers often dislike or even fear science (Crowther & Bonnstetter, 1997; Harrell & Subramaniam, 2014; Kazempour, 2014; Yuruk, 2011), and a lack of knowledge concerning the vocabulary may well be a reason (Muthwii, 2004). Preservice teachers have difficulty themselves with the expert vocabulary of science, and it is imperative that we prepare them to deal with not only their own shortfall but those of their future students (Bursal, 2012; Harrell & Subramaniam, 2014). It is vitally important that educators understand the language of science and how they can foster science language acquisition within their students. This article recognizes three challenges experienced by teachers and students when learning science. Research identifying these challenges is examined and several strategies for overcoming each are shared.

Challenges

Together our group has over 60 years of teaching experience working with students as well as preservice and inservice teachers. We've repeatedly found that the challenges of 1) a specialized vocabulary in the science content area, 2) the speed at which new terms are introduced in science as well as the nearly overwhelming vocabulary load associated with science reading, and 3) the struggles faced by English Language Learners (ELLs) as they learn the *language of science* continue to be an issue for preservice teachers.

Challenge 1: Specialized Vocabulary

As in other content area subjects, science has a specialized vocabulary that is, a register of terms and concepts particular to the subject. "In science, words are often given specific meanings that may be different from or more precise than their everyday meanings" (Michaels, Shouse, & Schweingruber, 2008, p. 4). A basic science register will include terms such as properties, action, and behavior words that may be familiar in common contexts but have different meanings in science. This register comprises the academic language of science, and it is truly a distinct language with its own structure and meanings. Students may be familiar with the register of story or narrative language. Included in narratives are descriptions, character roles, and settings among other factors. Transitions are smooth. In reviewing a science text, each paragraph consists of sentences that are one fact after another. Students unfamiliar with content area reading must be taught precisely how to approach a text of this nature (Shamsudin, 2009).

This specialized vocabulary of science is a common stumbling block for learners of all ages. In trying to use a dichotomous scientific key to identify wildflowers, one might come across the word hirsute (hairy). If not knowledgeable concerning Latin, then one truly may be at a loss as to what this word means; and it is only one of the thousands of expert words that must be used in order to identify a simple flower growing in a schoolyard. If the key choices are read aloud to students, interpretation can be even more confusing (i.e. hirsute sounds disturbingly like hair suit and can be confused by even adults who are listening to lecture or conversation). Consider the elementary teacher preparing a lesson on birds discussing down feathers and how they are close to the bird's skin to provide warmth. It would stand to reason that the uninformed teacher or student may use contextual clues, as all of us are taught to do, and naturally think that feathers used for flight would be called up feathers.

According to Aitchison (2003), words are precision instruments, which should be used with care and accuracy. Supposedly, educated people will know exactly which word to use and when, because in the course of their education they will have learned an exact meaning for each word. The overall assumption is that a basic meaning for each word exists. We call this the fixed meaning assumption (Aitchison, 2003; Benson & Greaves, 1981). The typical person holds an alternate viewpoint arguing that words cannot be assigned a firm meaning, and that natural language concepts have vague boundaries and fuzzy edges (Benson & Greaves, 1981). Take for example the word dog. We all know what a dog is but upon hearing the word, one may imagine a Doberman or dachshund. Perhaps a collie or a corgi? Does one see a dog sleeping, eating, running, waiting patiently at the door for its master, or none of the above? If this alternative viewpoint is correct, then it may be extremely difficult to depict the entries in a person's mental dictionary. Scientists using the precise and agreed upon language of science, focus on the fixed meaning assumption, which in turn causes difficulties if one is a science language learner who does not have the scientist's lexicon. If we consider words are labels for much larger concepts

(Li, 2009; Vacca, Vacca, & Mraz, 2014), merely learning a glossary or dictionary definition is completely insufficient. A word having a fixed meaning is constraining for comprehension of content area language registers. To develop concepts of words, students need extensive conversations in cooperative groups in order to thoroughly process information (Abidin & Riswanto, 2012; Johnson & Marx, 2009).

Challenge 2: Speed of Word Introduction and Vocabulary Load

The study of the sciences is naturally full of new as well as dense ideas so that the conceptual load for any student can be daunting. Considering a child learning English, this indeed may be a formidable task. Further, comprehension is inextricably connected to effective knowledge of vocabulary (Shin, Rueda, Simpkins, & Lim, 2009). August, Artzi, and Mazrum (2010) argue the need for explicit strategies to learn vocabulary that, in turn, support students' comprehension.

Science vocabulary is difficult because there are so many words. An unscientific survey of various elementary textbooks approved for adoption in our state provides a snapshot. The fourth grade textbooks the authors examined typically introduced 20-30 new words per chapter. If students complete a chapter every few weeks then they are being held accountable for learning 50 or more new words a month, which translates to over 400 new words in the school year for science alone. Admittedly, some words are familiar and may be used often, while others are science specific and may be difficult to remember, spell, define, and apply. Elementary students have limited life experience and when coupled with a disadvantaged background may have a more difficult time relating to those new words, particularly if introduced to them rapidly (Meara, 1980).

Many individuals report that science is a collection of facts and terms to memorize. In a groundbreaking study, Robert Yager (1983) analyzed secondary level science textbooks for vocabulary load and found that the amount of new vocabulary terms presented in such textbooks is higher than that recommended for junior high and high school foreign language courses. Later Groves (1995) re-evaluated three textbooks in the Yager study taking into account limitations expressed earlier and found one book, Modern Chemistry, still measuring above the recommended level for foreign language courses. Thus, it can be debated that for science textbooks at all levels the vocabulary load presented continues to be high and may contribute to misconceptions, lack of understanding of science, and avoidance of the subject (Pearson, Hiebert, & Kamil, 2007).

Further, research suggests students can reasonably and thoroughly learn only 8-10 words per week (Chall, 1996). Baker, Simmons, and Kame'enui (1998) found students who were learning many more words than that, but the knowledge of the vocabulary words was necessarily on a quite basic level of understanding. A possible solution might be to use strategies that relate the many vocabulary words contained in a single science unit of study, thereby offering the opportunities for multiple exposures of multiple words.

Challenge 3: English Language Learners (ELL) and the Language of Science

What if the science learner is not a native English speaker? This brings in further problems the pre-service teacher must manage. School science has a language all its own. Its vocabulary and sentence structure is complex—and aspects of argumentation and reasoning in science are different than in other disciplines. Thus, issues ELL students encounter may be categorized in four sections: the ELL student, language acquisition, science content, and vocabulary pedagogy. The teacher should be able to turn these challenges into opportunities for students.

ELLs meet a dual task: learning another language altogether and learning the academic language of Science content. These students typically do not have the language support they need outside of school since a school language is not included in standard conversations in the home, with their peers, in the community, and in their environment (Cummins, 2008; Shin, Rueda, Simpkins, & Lim, 2009). Clearly, if ELLs find acquisition of a new language challenging, then learning the academic language of science is doubly demanding.

In order for ELLs to acquire and develop language, it is necessary to have significant numbers of interactions in which the learner has ample opportunity to actively participate in both active listening and speaking with those persons Vygotsky refers to as more knowledgeable others (Vygotsky, 1962). Vygotsky described this phenomenon in his social constructivist theory, which aligns with Cambourne's Conditions of Learning (1995). According to both researchers, there is the need of a social milieu that provides considerable opportunities for interactive, purposeful talk especially in small groups. It is with more knowledgeable others that ELLs simultaneously will learn a new language and learn science vocabulary as well.

A constructivist pedagogy requires students to be actively involved both physically and mentally and to learn in authentic contexts, applying their knowledge to real world situations (Shin, et al., 2009). The simultaneous learning of science vocabulary in context and a new language is an interdependent relationship. Since vocabulary represents concepts, we do not learn words in isolation but in a meaningful text (Li, 2009). In this way, the meaningful text is the science content embedded with crucial vocabulary. Students using their home language as well as trying out (e.g. hypothesizing, approximating, getting feedback) their new language strive to accommodate and acquire science vocabulary and concepts.

Research and Practice: Dealing with the Challenges

The following table provides a glimpse at vocabulary strategies can be taught to pre-service teachers and that could be seamlessly integrated into a lesson focused on science content. The strategies suggested are only a window into a world of possibilities that exist, thus appropriate and beneficial strategies are not limited to those that are indicated.

Challenge 1: Specialized vocabulary

Two strategies seen in Table 1 tackle the issue of specialized vocabulary: The Frayer model and vocabulary self-selection (VSS). The *Frayer model*, created by Dorothy Frayer and her colleagues at the University of Wisconsin (Frayer, Frederick, & Klausmeier, 1969), is a graphic organizer that consists of a large square divided into four smaller squares with a circle or square at the center (see Figure 1). The Frayer model allows students to focus on a particular concept or phenomena which make this strategy effective for learning science vocabulary. Students will use the first square to share the definition in their own words and in the second square they will list essential characteristics of the vocabulary or concept they are studying. The last two squares are for examples and non-examples (Allen, 1999; Frayer, Fredereck, & Klausmeier, 1969). This strategy can be used individually, in small groups,

Table 1 Three Major Challenges to Science Literacy and Strategies to Meet Them

	Challenge	Strategy 1	Why this strategy works	Strategy 2	Why this strategy works
1	**Specialized Vocabulary**	*Concepts Circles or Frayer Model with Carousel*	Extensive conversations to construct knowledge. Refine word meanings for specificity	*Vocabulary Self-Selection*	High motivation with students' vocabulary choices Extensive conversations to construct knowledge.
2	**Vocabulary load and speed of introduction**	*Predictogram*	Stimulate prior knowledge of individuals Arouses curiosity to bring students into text before reading	*Concept of Definition Word Map with Carousel*	Input of personal examples for meaningful connections Extensive conversations to construct knowledge.
3	**English Language Learners**	*Word Sort*	Extensive conversations to construct knowledge. Explores, expands, and refines word meanings	*Semantic Maps with Carousel*	Extensive conversations to construct knowledge. Explores, expands, and refines word meanings

or as an entire class via a carousel activity. A sixth grade teacher might use the Frayer model with the carousel to explore several concepts in an astronomy unit. She would create several blank Frayer models with chart paper and post them around the classroom. Possible concepts might include stars, comets, satellites, planets, and dwarf plants (see Figure 1).

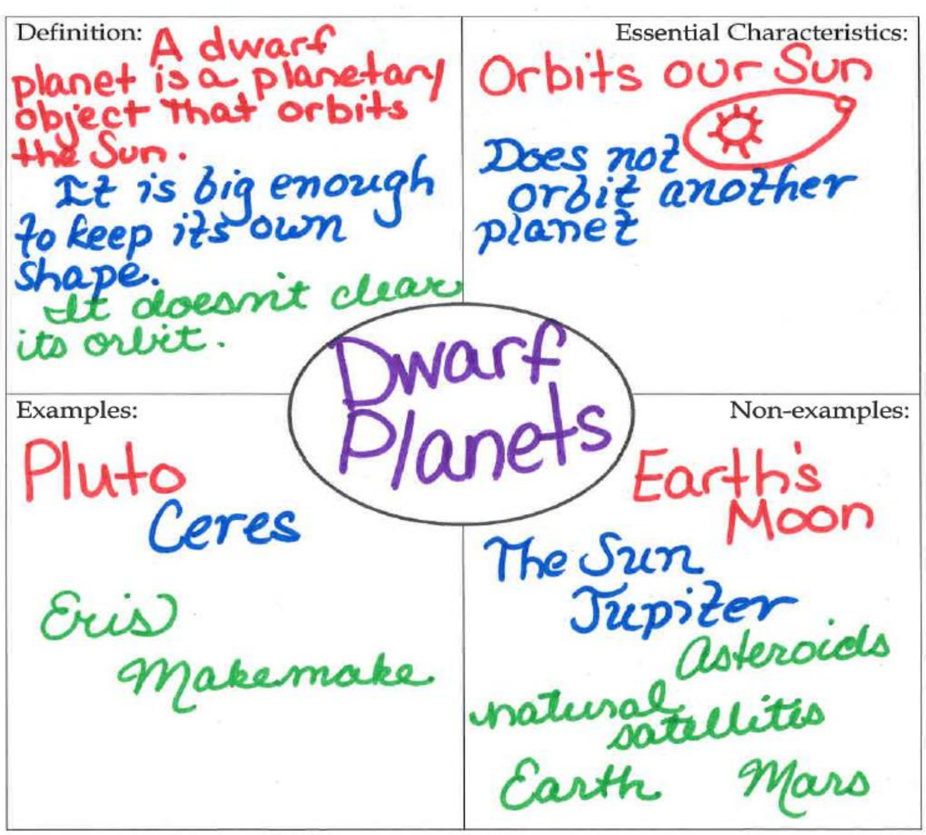

Figure 1. Three groups of students define and describe dwarf planets using a Frayer model.

Employing a carousel approach small groups, using distinct colors of ink, take a few minutes to complete as much of the graphic organizer before moving on to the next concept. Using a timer will help keep everyone focused. Once they reach the new concept they are encouraged to add to or correct the ideas shared by the previous group(s). Every few minutes the groups move to the next concept until the groups return to their original Frayer models where they evaluate the collected experiences, knowledge, and understandings of their class. The teacher would then take time to walk about the classroom with the entire class encouraging students to share, comment on, and summarize the information gathered.

The *vocabulary self-selection* strategy is a group activity focusing on vocabulary development. This particular strategy is successful because it allows for student choice. Students and the teacher will read a science passage with the goal of suggesting two or three words to include in the week's vocabulary study. Teachers encourage students to choose words they feel are important to the topic and that the class may not already know. Once the words are chosen the students share the words they would like to see added as well as a rationale for why they chose those particular words. Once all the words are shared the group will choose eight to ten words from the entire list to learn for the week. Students may create flash cards, place these words on the classroom word wall, or even enter them into their personal dictionaries.

Challenge 2: Vocabulary load and speed of introduction

In order to help pre-service teachers develop ways to engage their students, we introduce two more strategies. The *predictogram* is a prediction strategy that is generally used before reading. It is an exciting and personalized way to encourage engagement in the text via exploration of teacher selected vocabulary and will help with the issue of science vocabulary load and speed of introducing these new terms and concepts. Before reading the chosen text, the teacher must choose and list eight to ten key words from the text. Traditionally this strategy has been used when studying vocabulary and certain story elements (e.g., characters, setting, problem, and resolution). Students then place the vocabulary words on a chart indicating if they think the words will be used in certain parts of the story. However, we suggest using this strategy in the science classroom as well. A teacher might begin a unit on habitats with her third grade students by sharing a list of terms she has chosen for her class (e.g., carnivore, fish, habitat, food web, predator, fruit bat, niche, ecosystem, and river). Initially, in small groups, students will predict if the words will be used in conjunction with a particular habitat (e.g., tundra, desert, and ocean). As you can see there may be words that may be used with more than one category. This will promote discussions amongst students as well as between the teacher and her students. Students will then read and engage with the content returning to their predictogram later to see if their predictions were correct.

The *concept definition map* encourages students to make connections to key concepts and also helps ameliorate load and speed of vocabulary instruction in the science classroom. Similar to the Frayer model, the concept definition map is a graphic organizer that encourages students to define a concept, to describe the concept, and to share examples (see Figure 2). Value is added if used in a carousel format when student in the class has input on the various concepts/ terms. An eighth grade geology teacher may use the concept definition map to explore key terms for a chapter or as a way to review for an exam. He might choose to provide a template like the one below or encourage students to create their own maps. Concept definition maps can be used as entrance or exit slips, test reviews, or entries in a learning log.

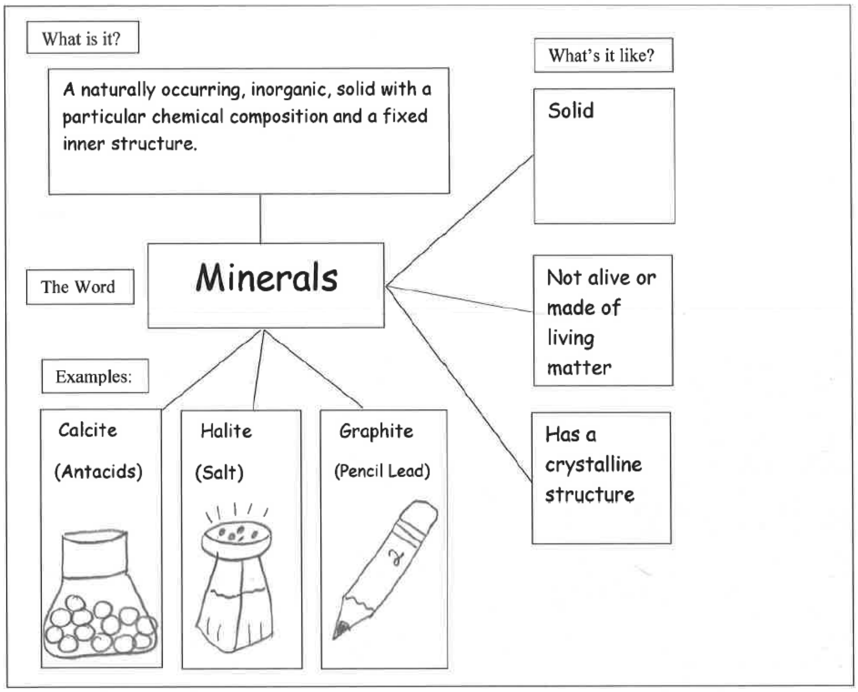

Figure 2. A concept definition map describing minerals: definition, examples, and characteristics.

Each of the previously described strategies are also helpful for ELLS as they stimulate prior knowledge. Personal examples for meaningful connections are integral, and the extensive conversation encourages both the construction of science content knowledge as well as the English language. Vacca et al. (2012) share that while key words are usually taught more often, "developing general academic or useful words is just as essential, especially for language learners" (p. 309). Michaels, Shouse, and Schweingruber (2008) encourage teachers to allow students to restate one another's ideas and to make personal connections to one another's ideas. This allows for the development of scientific ideas for all students involved. ELL students benefit in particular from these strategies as they see connections between concepts being discussed and later transcribed. Use of students' own ideas and language as in the Frayer and CD Word Map closely mirrors a "student led" language experience approach (LEA) (Van Allen, 1976). Vacca et al. (2012) encourage the use of LEAs to promote the learning of English for ELL students.

Challenge 3: ELL

We suggest the following two strategies, word sorts and semantic maps, for ELLs in the science classroom. This is due to the extensive discussions each affords as well as the open nature of these activities that allow students to make personal connections. There are two types of *word sorts* - an open and a closed word sort (Vacca, et al., 2012). Word sorts begin with a list of vocabulary written on cards. Student then take these cards and sort them into categories. In an open word sort the categories are decided upon by the students in each group. After sorting, groups might compare and attempt to guess what categories the others used. In a closed word sort the teacher identifies the main categories and students must place the vocabulary cards in the appropriate set. A high school biology teacher or university professor might choose to use a word sort at the beginning of class to expose students the different levels of classification. A modified word sort may work better when teaching a concept containing many integrated parts. Posting this modified sort as a visual outline on the wall of the classroom further supports understanding and vocabulary attainment. One author uses this strategy when exposing students to the kingdoms of life. Large note cards are used to create a word list of domains, kingdoms, and some phyla. Additional cards list examples of each kingdom or domain and while still others list characteristics or specific examples. The cards are randomly distributed to students or student groups. Kingdom cards are identified. Students discuss characteristics of each kingdom and come to a shared agreement of the order in which these should be posted from least to most complex around the room. The instructor prompts students to identify domain cards and together they discuss which kingdoms belong in which domains. These cards are then posted (see Figure 3). The instructor uses thoughtful questioning and students work together to discuss and post key terms in appropriate locations around the room. Posting cards under the domain and kingdom heading cards creates a limited but logical outline format as they talk, describe, compare, and contrast the terms. Obviously this topic is too broad to cover in one class period, so cards are removed and reposted (with review) the next time the class meets. Each time the lesson is continued students are able to review previous vocabulary by recreating the outline on the wall. This review provides a framework upon which students continue to grow their understanding.

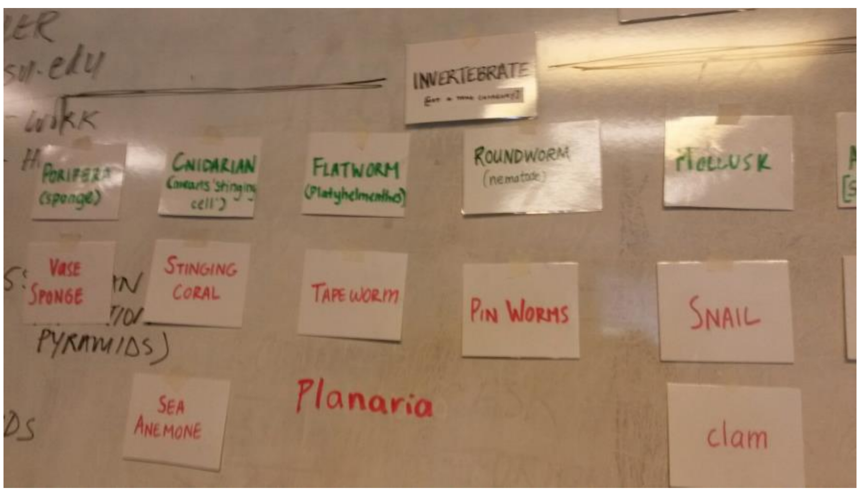

Figure 3. Modified word sort of kingdom and domains from Life Science for Elementary Teachers (BIOL 3000).

Semantic mapping is a strategy commonly used to organize important information for readers and writers (Vacca, et al., 2012). However, this strategy can be employed during vocabulary study as well. The teacher begins by choosing a key term from the reading and writes it on the board. Students are then asked to brainstorm as many words associated with the key term. Depending on the academic level of students the teacher may choose to serve as scribe writing the terms on the board or students may wish to use index cards or Post-it® Notes to write these down. Once the brainstorming activity is finished students take time sharing their associated words suggesting categories for the word bank as it grows. A middle school science teacher might ask his students to brainstorm words and terms associated with their topic of rocks. The students might then generate words like outcrops, gneiss, solid, minerals, hard, smooth, salty, sedimentary, etc. Together as a class, in small groups, or individually, his students would begin organizing these associated terms in a manner that makes scientific sense (see Figure 4). Semantic maps are organic and change as the discussion evolves, and they will rarely resemble a previous map as they are graphic representations of learners' thinking (Novak & Gowin, 1984; Williams, 1998). Students may use semantic word maps to study for an exam or to organize thoughts for an essay or journal entry. Teachers can use the semantic word maps as pre and post assessments. Semantic mapping is also useful in identifying possible scientific misconceptions (Hoz, Bowman, & Kozinsky, 2001; Novak, 1983; Wandersee, 1990). Both the word sort and semantic map are powerful tools for ELL students as it gives all students an opportunity to explore, expand, and experience the subtleties of word meanings.

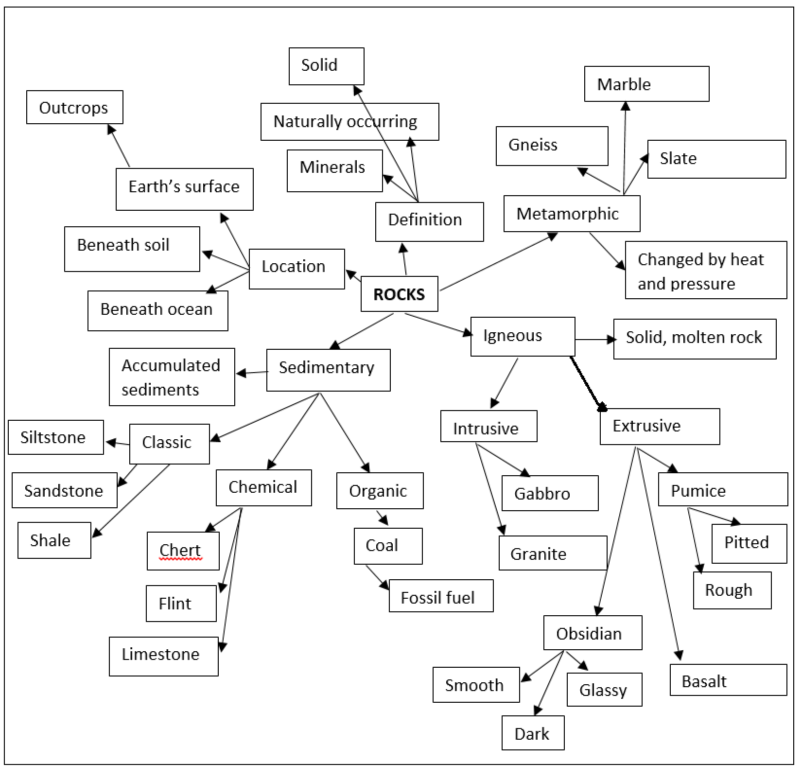

Figure 4. Semantic word map organizing words associated with the concept of rocks.

An additional way to deal with these major challenges in developing science literacy, especially with language learners, is Total Physical Response (TPR). In fact, TPR may be used to increase vocabulary fluency in any subject (Asher, 1966, 1969). TPR was developed as a language teaching strategy by James Asher and is based on the coordination of language and physical movement. Asher wondered why individuals found it easy to learn a first language but encountered great difficulty learning a second language. Two explanations proposed are that many teachers use methods unlike those used while learning a first language and that stress is often generated as individuals attempt to learn their second language. Therefore, Asher focused on creating a stress-free approach that made great use of techniques found in first language learning experiences; a stress free environment, relaxed, pleasurable practices, and focusing on meaning by the use of movement and or models and props. Many agree that colleges and universities are negligent in not training future language teachers to be highly proficient in the handling of this powerful tool (Richards & Rodgers, 2001).

Total physical response lessons typically use a wide variety of facial and body movements coupled with vocalizations, such as voice tone, pitch, and volume. TPR also makes great use of realia (everyday objects used as teaching aids), posters, and props in the lessons for students. Thus TPR is an excellent way to reinforce content information. Use of TPR in a health education lesson would be the teacher pointing to their elbow and wrist and moving their arm when talking about muscle origin and insertion. An example of use in a biology class might be the educator providing a diversity of cones from various conifers for students to examine as the class talks about gymnosperms versus angiosperms (flowering plants). Both of these approaches are ways to foster understanding and comprehension. Simply talking about concepts is not nearly as rich or engaging as actually moving your own arm as you think about muscle attachment or experiencing how different the exposed *naked* seed of the gymnosperm is from the 'covered seed' within a ripened ovary of the angiosperm. Singing songs particularly when they are coupled with body movement or using rhymes are additional ways to couple vocabulary strategies in science with content acquisition. Because of its participatory non-stress approach, TPR may also be a useful alternative teaching strategy for students with dyslexia or related learning disabilities, who typically experience difficulty learning foreign languages with traditional classroom instruction (Zink de Diaz, 2005).

Conclusions

Because science is often seen as having a language all its own the ability to use and understand that language is becoming increasingly important (CCSS, 2010; NGSS Lead States, 2013). The Next Generation Science Standards (NGSS Lead States, 2013) point to the importance of acquiring the important language intensive practices of argumentation, communication, explanation, and questioning. All may be taught using language practices that are both receptive (listening and reading) and productive (speaking and writing). Even as early as 1993 Project 2061 (AAAS, 1993) set forth the goal of creating a scientifically literate populace, defining it as,

> the belief that the science-literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes. (para. 19)

We actively use the strategies shared in this article in our classrooms to prepare students seeking to become educators. When these pre-service teachers experience personal success with the approaches they will be more likely to implement them with students of their own. Strategies shared are only a tiny sample of what we use and what is available to science educators who want to more fully integrate vocabulary instruction into their classroom practice. We encourage readers to further pursue content area reading strategies that will make learning the specialized vocabulary of science easier for their students (e.g. Allen, 1999; Vacca, Vacca, & Mraz, 2014) and to add more strategies in teaching pre-service science teachers. The research-based vocabulary strategies such as those mentioned in this article address the well-recognized and documented challenges in the science classroom; highly specialized vocabulary, speed of introduction of new words coupled with vocabulary load, and supporting ELL will serve all learners in the content area of science.

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