ScienceSpeak: Common vs Technical Science Language

By Jacquelyn Kelly, PhD

Introduction

Language is a medium by which people communicate. It allows us to understand what others are thinking and express our responses. In the classroom, language has been the primary tool for distributing, discussing, interpreting, and building knowledge despite whether it is through transmission, social constructivism, or situated cognition. Because of this importance, it is imperative to understand how students use and develop language in the classroom.

But language in the context of a science or engineering classroom is not necessarily consistent with every day, colloquial speak. Vygotsky illustrated this point by distinguishing between everyday concepts and scientific concepts (Vygotsky, 1986). He argued that in order for students to create formal, scientific concepts, it is necessary to create rich contextual and social environments. So, in terms of an engineering or science course, for students to "speak engineering" or "speak science", we must treat language as a concept and explicitly teach students the languages of science or engineering. To further understand this claim and its implications in science learning, some background on academic language and its relationship with conceptual learning theories will be discussed. Because work on this topic in the context of engineering is scarce, the science context will be presented as a parallel.

Rationale

Language and Conceptual Learning

The goal of any science instruction is to move students towards a normative view of how the world works. Engineering classrooms aim to transition students towards understanding applications of these fundamental explanations of phenomena for some particular application. Learners are often described as creating models of concepts to explain and predict phenomena. Gilbert, Boulter, and Rutherford (1998) describe models as simplified viewpoints capable of producing many explanations for a particular phenomenon. They claim that models can represent ideas, objects, events, or processes. Models can vary greatly in simplicity, however must be able to provide five different types of explanations: (1) intentional explanations, which provide justification of relevance and importance, (2) descriptive explanations, which answer how the phenomena behaves, (3) interpretive explanations, which enable classification and comparison to like cases, (4) causative explanations, answering what causes the specific phenomena, and (5) predictive explanations, allowing for predictions to be made about like situations or similar phenomena (Gilbert et al.,1998). Though even strong models have limitations, if a model cannot offer each of the types of explanations, it is deemed as faulty. Model development occurs through analogical reasoning in which a learner identifies similarities between a previously held idea seen as similar to the actual phenomena, the *source*, and the actual phenomena, the *target* (Gilbert et al., 1998). These analogies are used to construct the model in hopes that the source will accurately, and in all five ways, explain, the target. It is this explanatory process that requires explicit and intentional academic language.

Language acts as a communicative tool allowing students to explain what knowledge exists in their minds. *Mental models* are models are these personal representations of the target that occur in the mind, and are therefore only fully understood by the person by whom it has been contracted (Gilbert et al., 1998). However, if the model is explained by that learner (through verbal, written, or kinesthetic communication), it becomes an *expressed model* (Gilbert et al.,1998). The expressed model can then be compared to the *normative*, or scientifically accepted, model. Without language, accessing students' mental models would be incredibly challenging. Even with language, without a clear understanding of the student's fluency in academic language, it is difficult to determine the strength of the mental model. This makes it imperative to understand how students use academic language and how it differs from colloquial language.

Diverse and Changing Engineering Challenges

Engineering is the application of science for social progress and innovation. The future of progress depends on scientific and engineering literacy which can respond to global demands. The National Academy of Engineering (NAE) released two publications referencing the future of engineering and the needs for educating future engineers. In 2004, *TheEngineer or 2020* was published, highlighting the changing environment that future engineers would work within (National Academy of Engineering, 2004). A focus of this book was the change from local to global engineering. It discussed how the Engineer of 2020 would need to be able to operate from a global perspective, being able to work in global teams, analyze global impact, and create global solutions. Four years later, NAE published the *Grand Challenges for Engineering* (National Academy of Engineering, 2008). These global challenges, including making solar energy economical, managing the nitrogen cycle, securing cyberspace, reinforced the necessity for global and large-scale engineering. Focusing on global problems requires a common speech not only within a common language such asEnglish, Spanish, or Chinese, but also within more specific academic engineering context. This makes it crucial that engineers "speak engineering" and that engineering speak is examined just as a second language acquisition would be. In order to understand this academic language acquisition process within the classroom, we must first understand some about language development and the differences between colloquial and academic speak.

Language Development

Yeung and Werker (2009) examined how young children learned sounds with relatively little teaching. They discuss that previous literature supported the claim that infants learned to distinguish sounds based on statistical frequency analysis of auditory input. However, in a series of three experiments, they found that learning to distinguish sounds was dependent not only on frequency of input, but also on visual cues provided during input (Yeung & Werker, 2009). This suggested that infants who were given clues to the functionality of sounds upon encoding were more likely to be able to distinguish or learn the sounds. This finding is consistent with cognition literature on memory and goal setting. Patalano & Seifert (1997)identified the usefulness of predictive encoding. They found that at the time of goal setting, students were more likely to recognize opportunities to achieve their goals if they were presented with cues, or tools and strategies, to do so at the time of encoding. These two ideas show that in learning, students must not only be taught words, but also be taught meaning and utility of words upon their introduction. In an engineering or science classroom, for example, this would require that when teaching students about the measurable property *strength*, students are not only told what it means, but are given opportunities to see how it would be used to characterize materials, guide material selection, or test material failure conditions. However, though helpful to recognition, this may not ensure students understand word meaning.

Markman (1991) discussed three assumptions made by language learners that inhibited understanding of word meaning: the whole object, taxonomic, and mutual exclusivity assumptions. The whole object assumption, made by language learners, applies a word to the entire object rather than a category it might exist in or as a descriptor of its individual parts. The taxonomic assumption enables language learners to classify objects that a word may refer to based on classifications or categories. For example, if someone uses the word *boat*, the language learner first deploys the whole object assumption and assumes that *boat* refers to the entire object. Second, the language leaner utilizes the taxonomic assumption and assumes that *boat* probably describes other large objects that float in water and have similar properties to the observed object. The mutual exclusivity assumption allows language learners to assign labels to parts of objects, or to objects that may not belong in general categories (Markman, 1991). For example, rather than call every object that floats in water a *boat*, a learner may learn to distinguish *rafts, jet skis*, or *cruise ships*. While these things all fulfill the general requirements of a *boat*, they are mutually exclusive of each other. For engineering or scientific language, teachers must realize that students learning engineering and science language are making these same assumptions. Students are classifying like terms while assigning mutually exclusive labels to others. Without being aware of this as an instructor there can be no feedback which may compromise proper encoding allowing these assumptions to hinder learning.

In the classroom, teachers must be clear and discuss the use of limitations and proper associations of terms. The use of operational definitions, or terms defined within specific contexts or uses, can help students understand which assumptions may or may not apply. For example, upon introduction of new terms, teachers can discuss the contexts that the terms may or may not be appropriate for. This enables students to become comfortable with the generalizability and exclusivity of new words. This will help compact limitations of the whole object, taxonomic, and mutual exclusivity assumptions. Additionally, it allows students to understand the use of assumptions and limitations, which are concepts central to the nature of science.

Scientific Language

Scientific language varies from everyday language. Roth (2000) observed a class of middle school science students to examine how gestures and language influenced cognitive development of introductory physical science topics. Just as in primary language acquisition, students' gestures in science preceded their utterances to describe scientific phenomena. He found that, as students became more proficient in scientific language, gestures become consistent with utterances. This, he claimed, provided evidence that scientific language is a second language that needs to be acquired (Roth, 2000). But how can we tell if someone is fluent in scientific language? In his book, *Talking science: Language, Learning and Values*, Lemke classifies it as the degree to which one can interact in the scientific community. According to him, scientific language is acquired through interaction with this community (Lemke, 1990). However, according to Yeung & Werker (2009) and Patalano & Seifert (1997), immersion may not be enough. Immersion in the scientific community would surely allow students opportunities to receive sufficient auditory input to be able to statistically analyze frequency of sounds; however, it may not guarantee that students receive the appropriate functional cues to achieve proficiency. Parkinson described a variety of "literacy events" that college science students are asked to engage in including experimental research and write ups, lab experiences including lab manuals, tutorial sessions and problem solving, lectures with lecture notes, tests, problems and calculations, and essays (Parkinson, 2000). Of all these events, students engaged in writing summary-based lab reports 85% of the time (Braine, 1989). While this may give students a variety of functional cues for scientific language, it does not provide ample input so that students can statistically analyze the frequency of auditory input necessary for understanding new language. In order for students to best learn engineering or scientific language according to this model, engineering and science instruction should provide ample opportunities for both emersion and literacy events as defined above.

Summary and Implications

In order to monitor student conceptual understanding, instructors must heavily rely on language. However, in science and engineering, colloquial language varies significantly from science and engineering technical language. As a result, there must be a common academic language. This requires students to acquire an additional dialect of their language to be used for the context of science or engineering. Additionally, the future of science and engineering has global demands, making it necessary to have common language and understanding among the fields. This, again, emphasizes the importance of teaching students to become proficient in science and engineering academic language. Various approaches have been utilized to build proficiency in second language acquisition. These can be adapted for science and engineering contexts so that students become proficient in science and engineering language.

Instructors and students must be aware of the necessity to acquire additional language for the learning of science and engineering. Without this understanding instructors may make incorrect assumptions about student knowledge. Students may get frustrated or misinterpret information. Viewing scientific or engineering language is necessary but seeing it that way may cause challenges. Both use the medium of English. So, to someone outside the community, they appear the same. And it is this assumption that must be avoided. So, in the least, for students learning science or engineering, it must be made explicit that they too must learn the language associated with it.

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