Work in Progress: Do students need to learn to speak "Engineering-ese?" Conceptual change as language acquisition in engineering

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***Abstract*—Conceptual change is often approached with a concrete epistemology in which students must replace their misconceptions with correct conceptions. Drawing upon the literature and our research, we propose that we need a new, discursive epistemology that describes conceptual change as language acquisition.**

Keywords-philosophy; epistemology; discourse; language; conceptual change; engineering education

I. INTRODUCTION

"The real problems of the differences between scientific concepts and those characteristic of everyday life have less to do with conceptual difficulties or misconceptions… and more to do with the problem that people do not have access to contexts in which science talk is functional and necessary." [1]

When conceptual knowledge is discussed among educators, it is often described as a concrete object that resides within students' minds. This concrete epistemology is often conveyed through the verbal imagery of terms such as *mental models* or *replacing* students' misconceptions with correct conceptions.

In this work-in-progress, we propose that this concrete epistemology by itself is inadequate to describe and explain the learning process, and in particular, conceptual change. Drawing on multiple theoretical traditions that describe the role of language in cognition, we describe two key implications of changing to a more discourse-focused epistemology: (1) expert's perception of students' conceptual difficulties is as much a function of language as it is a function of science and engineering and (2) engineering students' conceptual difficulties are rooted in their difficulties in distinguishing the engineering dialect of English - "Engineering-ese" - from colloquial dialects of English.

Many words from colloquial English (for example "stress" or "if and only if") mean subtly different things in Engineering-ese, and students who are unaware of this difference struggle to develop accurate, consistent concepts and communicate these concepts. We provide evidence from the literature and our previous research to demonstrate that students struggle to switch between colloquial English and Engineering-ese and that this ability to switch between dialects may be critical to conceptual change and learning.

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II. FOUNDATIONAL THEORIES: LEARNING

A. *Constructivist theory*

Constructivist theory argues that students need to build their knowledge upon their own prior knowledge. Hence, the emphasis of constructivism is the knowledge which a student possesses. Constructivists argue then that learning happens when students are "forced" to access their prior knowledge, wrestle with it, and purposefully construct new knowledge. Constructivist theory is built on a concrete knowledge epistemology, so conceptual change is the process of students replacing their misconceptions through reasoning [2].

B. *Sociocultural theory*

The sociocultural perspective argues that new knowledge is only truly meaningful within the context of a group of people. Consequently, conceptual change and development is not so much the creation of new knowledge within a student, but the ability to learn the values and distinctions that are important to a certain group. All knowledge, it is argued, is immutably situated in contexts of learning and application, and efforts to abstract or generalize outside of recognizable social contexts will interfere with learning [3].

C. *Language in Conceptual Change*

Saljo argues that conceptual change research should move to an emphasis on discourse rather than concepts or other intangible constructs [1]. This stance has not inspired a great deal of language-centric research efforts, although some conceptual change researchers are now concerned with the role that writing and speaking play in conceptual change [4].

III. FOUNDATIONAL THEORIES: LANGUAGE

The philosophy of language is vital and central to this inquiry, but is currently a source of questions rather than answers [5]. We are continuing to investigate philosophical works on the nature of language in order to understand the broader context and develop conscious, informed stances in the development of this research

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However, studies demonstrate the interconnectedness between language and concepts. For example, native German and Spanish speakers conceive of objects differently based on the gender that their languages attribute to the object. Germans describe bridges (feminine in German) as "beautiful" and "slender," but Spanish speakers describe bridges (masculine in Spanish) as "sturdy" and "towering [6]."

IV. Two Implications of Engineering-ese

A. Expert's Interpretations of Novice Language

Researchers interested in students' ways of thinking almost universally access that thinking through language. Thus, research efforts are colored by an as-of-yet invisible process of interpretation and translation from the students' language (which may be entirely engineering-ese, entirely colloquial, or a mixture of both) to the researchers' engineering-ese.

Research methodologies and instruction must consider how experts' use of terms and distinctions differs from students' use. When exploring conceptual change interviews, we have found that pairing a content novice with a content expert during analysis has revealed that experts struggle to understand the difficulty that students have in acquiring new vocabulary in a discipline [7]. For example, when analyzing students' understanding of mechanics of materials, the novice researcher could better understand what the students were saying about stress and strain and would perceive that the students possessed a higher quality of conceptual understanding than the expert.

B. Students' Learning Through Engineering-ese

Based on how the gender of nouns moderates conceptions, we propose that language moderates conceptual change by directing the formation of concepts and how we access or use them. Furthermore, these distinctions must be seen as relevant and important to communication. For example, we might assert that the concept of an *emergent* process, processes such as diffusion and equilibrium [8], will form concurrently with the acquisition of the term *emergent* into a students' discourse.

Similar to how the gender of a noun influences a speaker's perception of an object or concept, the linguistic context in which certain terms were learned can affect our perception and understanding of the concept as well as what features we consider to be important about that concept.

The concept of shear stresses and strains in Mechanics of Materials and the concept of exclusive-OR in Boolean logic provide two examples of the importance of the creation of linguistic distinctions [7].

When students develop their initial conceptions of shear stresses and strains, they initially connect the term shear with arrows in the vertical direction. For example, students have said, "the stress is vertical, so it would be shear stress." This failure to distinguish "shear" from "vertical" may be caused by a lack of situations in which a distinction between vertical and shear were linguistically useful. Shear appears to be a difficult concept to acquire because it lacks linguistic purpose – students are not placed in situations where messages of importance rely on the distinction between the words *shear* and the idea of vertical forces [7].

In contrast, students are taught the difference between inclusive-OR (I can own a cat or a dog OR BOTH) and exclusive-OR (I can turn left or right, BUT NOT BOTH) by making the distinction that exclusive-OR *excludes* the case when both conditions are true. Students quickly learn this distinction as it proves relevant in conversation [9].

The emotional and linguistic implications of language also impact what students perceive about terms and concepts. For example in Boolean logic, the concepts of "A *if and only if* B" and "A *if* B" are distinct. However, they are the same concept in English, except the "*and only if*" is emphatic. When translating technical specifications into logic expressions, students rarely perceive the presence of the phrase "and only if" and automatically retranslate the specification into A *if* B. Because the *"and only if*" is an emotional tool rather than an informative tool in English, students fail to see its informative importance in Engineering-ese. Students who can parse *"if and only if"* as a unique Engineering-ese term, could also conceptually distinguish "A *if and only if* B" from "A *if* B".

V. Future Considerations

If conceptual change in engineering is fundamentally the acquisition of a new dialect, then should instruction emphasize communication as more than "just a soft skill?" Can we provide evidence that the best-practices for language acquisition and communication may actually be the best-practices for learning engineering?

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