AC 2012-4076: USING SYSTEMIC FUNCTIONAL LINGUISTICS TO ANALYZE ENGINEERING SPEAK IN AN INTRODUCTORY MATERIALS SCIENCE AND ENGINEERING COURSE

Jacquelyn E. Kelly, Arizona State University
Prof. Stephen J. Krause, Arizona State University

Stephen J. Krause is a professor in the School of Materials in the Fulton School of Engineering at Arizona State University. He teaches in the areas of bridging engineering and education, capstone design, and introductory materials engineering. His research interests are evaluating conceptual knowledge, misconceptions and their repair, and conceptual change. He has co-developed a Materials Concept Inventory for assessing conceptual knowledge of students in introductory materials engineering classes. He is currently conducting research on misconceptions and development of strategies and tools to promote conceptual change in materials courses.

Dr. Dale R. Baker, Arizona State University

Dale Baker is a Fellow of the American Educational Research Association and a Fellow of the American Association for the Advancement of Science. She is on the Advisory Board of JEE and is a Former Editor of the Journal of Research in Science Teaching. Her work focuses on equity issues in STEM, teacher professional development in STEM, and engineering education more generally.

Using Systemic Functional Linguistics to Analyze Engineering Speak in an Introductory Materials Science & Engineering Course

Abstract

Students can use technical language consistent with science and engineering norms yet may not understand the meaning of these words. This phenomenon has been examined in science classrooms by many researchers. However, little work has been done in the context of engineering which requires students to not only be able to use engineering terms and understand natural science concepts, but to also be able to clearly articulate and understand these concepts with respect to their use in engineering applications. In order to understand and interpret student academic language, a lens to analyze and quantify it is required. This paper will answer the research question, "How can student proficiency of engineering academic language be assessed?" To answer this question, a functional view of linguistics will be used as a theoretical framework for interpreting engineering academic language. While traditional views of language focus primarily on grammar, which works with the structure of sentences, a functional view of linguistics examines the relationships between these structural components of language and their contexts and meanings. This theoretical lens is particularly relevant to engineering language, since understanding its use in the context of engineering design is of utmost importance. Systemic functional linguistics (SFL) will be used as a theoretical framework for analyzing engineering speak in an introductory materials science and engineering course. A written engineering design task, asking students to use as much engineering knowledge and vocabulary as possible to discuss the design of a bicycle. This task was administered three times to students over the course of a semester. The potential for using an SFL framework was demonstrated by analyzing a student's engineering speak as it progressed across a semester of the course. Preliminary results suggest that student language use can be monitored and assessed successfully over the course of a semester, and could potentially allow an instructor to make instructional decisions to enhance and maximize student learning. Challenges, affordances, and results of interpreting engineering speak through an SFL lens will be discussed.

Introduction

Language is a communication tool that allows students to explain what knowledge exists in their minds. Mental models are personal representations of target concepts that occur in the mind, and are therefore only fully understood by the person who has constructed them[1]. However, if the mental model of the concept is explained by the student (through verbal, written, or kinesthetic communication), it becomes an expressed model[1]. The expressed model can then be compared to the normative, or scientifically accepted, model to test its validity. However, without language, accessing students' mental models would be incredibly challenging. Even when language is used, without a clear understanding of the student's fluency in that academic language, it is difficult to determine the validity of the mental model. This makes it imperative to understand how students use academic language in the context of engineering design and applications.

Language as Foundation and Meaning

Matthiessen, Slade, and Macken[2] describe the challenge of assessing student writing. They report that, it is difficult to assess student writing because reliable objective frameworks often only assess the student's written product, but subjective frameworks, which assess the writing process and reveal its insights, lack reliability. Essentially, reliable objective assessment misses much of the student's knowledge, while more valid subjective assessment lacks the ability to provide repeatable, consistent results. The authors argue that this challenge can be overcome by utilizing a framework for language analysis that allows for objectivity and makes explicit the connections between grammar, meaning, and context. Language must be measured across two dimensions: actualization and stratification[3,2]. Actualization refers to language as a tool that is used and encompasses the ability to use it, the thought processes used while constructing it, and the actual use of language[2]. This takes into consideration the fact that language is a process, not just a product, and has the potential to create meaning. Stratification, however, is much more fundamental and encompasses language use in terms of grammar, semantics and phonology[2]. These linguistic devices incorporate word construction, sentence development, pronunciation, and encoding and decoding of text. Matthiessen, Slade, & Macken[2] describe the necessity of using these two dimensions:

> Linguistic processing is not a matter of spontaneous creation; it relies on a shared system. Similarly, communication is possible precisely because the levels of language-in-context interlock. Grammar expresses semantics, and through semantics, contexts of use and culture; these higher levels are created by grammar. These levels have evolved together. (p. 177)

In order to address and assess this multidimensional perspective of language, the authors suggest the use of a holistic framework: systemic-functional linguistics. To understand the use and meaning of student academic language, the authors will show how a systemic functional linguistics framework can be applied.

Background

Systemic Functional Linguistics

Systemic functional linguistics (SFL), as described by Halliday and Matthiessen[4], enables the researcher to examine the relationship between fundamental language use (stratification) and its context (actualization). This allows for understanding how particular words, intended audiences, and medium of communication used are related to the meanings, contexts, and situations that they are used for. To do this, SFL examines how foundational grammar is used to create register and meaning. This is done by examining various components of register (field, tenor, and mode), and meaning (ideational, interpersonal, and textual) and how those components interact. These relationships are shown in Figure 1 and are explained in the following sections.

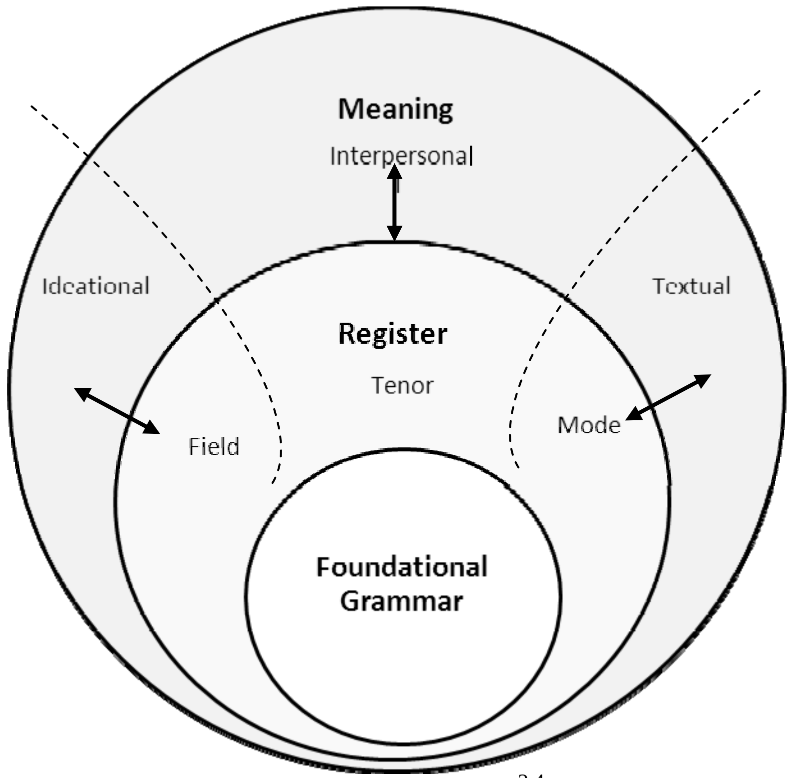

Figure 1. Components of Systemic Functional Linguistics.[2,4]

Register refers to the context or setting of the language. Lemke[5] describes differences in the languages of various school subjects such as literature, science, history, music, math and economics as registers:

> These languages are all, of course, parts of English. They use the same grammatical and semantic resources, but they use them in different ways, for different purposes[5] (p. 155)

These different communication preferences and purposes comprise each subject's register. In science and engineering, registers may be made up of technical vocabulary, specific to intended audiences and explicit forms of verbal and written communication such as scientific presentations or lab reports. In engineering specifically, design proposals and language use in the form of actionable design and application is required. These characteristics make up a distinct engineering register. It is apparent that register is dependent on multiple subtleties within each language. To better understand the complexities of the register, Halliday & Matthiessen[4] introduced three distinct subsets of the register.

Register can be further divided into field, tenor, and mode as shown in Table 1. The first, field, refers to the subject matter context. For example, the specific topic or discipline for which the language is being used, like engineering. Field can be made up of the context or setting for the language. For example, if an engineer is examining information for the purpose of developing a design recommendation, then the context of the language would be that of engineering design. Field also includes the technical vocabulary associated with the context (the specific engineering terminology) and the concepts required to communicate within the context (the prior knowledge and conceptual understanding of engineering concepts related to the context). Returning to the example above, if an engineer is evaluating information for the purpose of developing a design recommendation, the linguistic field is made up of engineering terminology, knowledge of engineering concepts, and the situational context of a design task. The second variable of register, tenor, refers to audience context or to whom one will be communicating. For engineering students this may include instructors, peers, engineers or the general population. For practicing engineers this may include colleagues, superiors, clients or manufacturers. Included in tenor is the mood that the language communicates. For example, if an engineering student is communicating in class with his or her peers, the mood may be casual or inquisitive. In contrast, if a practicing engineer is providing a design recommendation to a manufacturer, the mood might be professional and authoritative. Typically, the tenor dictates which mode of communication is most appropriate. The third variable of register, mode, refers to the medium of communication or specifically how one will be communicating. For example, communication can occur verbally or through writing. The in-class interactions between peers, as described above, might call for a verbal mode. However, the engineer's design recommendation may suggest a formal written mode. Mode also includes how words are used and how sentences are structured, dictating, for example, if they will be short and concise or long and complex. Together, field, tenor and mode create the linguistic register.

Table 1
Variables of the Linguistic Register

Variable	Description	Engineering Example
Field	▪ subject matter context ▪ vocabulary ▪ subject specific concepts	▪ engineering design ▪ failure, deformation, stress, etc. ▪ engineering knowledge required
Tenor	▪ the intended audience ▪ the required mood	▪ a client or manufacturer ▪ professional, authoritative
Mode	▪ medium of communication ▪ textual structure	▪ a formal written brief ▪ complex explanatory structure

In addition to register, the other dimension of SFL is meaning. Meaning describes not the actual words and context as register does, but rather the meaning of those words. For example, a student may be trying to explain the process of designing a bicycle. The register is composed of the actual words used, the intended audience, and the written medium. However, the meaning of the words is based on: the student's prior knowledge; how the student intends to communicate with the intended audience; and how the words are written in order to communicate most effectively. To better explain meaning, Halliday & Matthiessen introduced three subsets of meaning[4].

Meaning is divided into three metafunctions: ideational meaning, interpersonal meaning and textual meaning as shown in Table 2. The first metafunction, ideational meaning, includes language strategies that help create knowledge building and explanations of the natural world. For example, for an engineer developing a design recommendation, ideational meaning would involve the engineer's ability to use prior knowledge and appropriate language to support the recommendation. The second metafunction, interpersonal meaning, encompasses resources that allow for engaging in social interactions. For example, for the engineer creating a design recommendation, this may include strategies to keep the reader's interest while maintaining confidence in the engineer. In the area of verbal communication, this would include an understanding of when to take turns speaking, when to question, when to explain, when to accept or when to refute. Interpersonal meaning relies heavily on a person's ability to interpret, respond to, and create and maintain social interaction. The third metafunction, textual meaning, includes resources necessary for creating communications that will be coherent and interpretable. In creating the design recommendation, a practicing engineer will ensure that the recommendation is logical and coherent. In addition, the engineer will check that all language and content used is relevant to the design. These functions monitor coherence and relevance that comprise textual meaning. Together, the three meaning metafunctions (ideational, interpersonal and textual meaning) allow for one to socially engage an audience with the use of the register and utilize field, achieve tenor, and determine mode. Together the two main aspects of SFL (register and meaning) including their six components (field, tenor, mode, ideational meaning, interpersonal meaning and textual meaning) describe how language context and meaning are related.

Table 2
Metafunctions of Linguistic Meaning

Metafunction	Included strategies	Engineering Example
Ideational	▪ representation of building knowledge and explaining the world ▪ creating complex ideas	▪ supporting language claims with engineering knowledge ▪ fully explaining thoughts
Interpersonal	▪ social communication ▪ turn taking	▪ establish interactions ▪ questioning, commanding, denying, accepting, refuting, stating
Textual	▪ creating coherence ▪ determining importance and relevance	▪ making sure a design recommendation makes sense ▪ checking all content is relevant to intended design

Adapted from: (Halliday & Matthiessen, 2004; Martin, 2009)[4,6]

Assessing Engineering Speak with SFL

To determine and understand if engineering academic language can be quantified within a systemic functional linguistics framework, the writings of students in an introductory materials science and engineering course were analyzed. To demonstrate the process for this paper, one student's engineering language was examined and assessed over the course of the semester. The undergraduate student participated in the writings of the semester. Participation was voluntary throughout and was integrated as part of the course as a part of some homework assignments. The course ran during a 15-week semester with the class meeting for seventy five minutes twice per week.

In order to assess the student's engineering academic language, writing samples were collected three times over the course of the semester. To do so, a Written Engineering Design Task was administered as part of the course as a homework assignment and was deployed before instruction at week 1 and during instruction at approximately weeks 5 and 11. These writing samples allowed for tracking the student's changes in engineering academic language as the semester progressed. The writing prompt was as follows: "Using as much of the vocabulary and concepts of materials engineering as you can, describe how you would engage in the materials selection process for deciding what materials should make up the various parts of a bicycle. Be sure to explain what engineering information you are using and how you are using it to make your decision." This provided insight to how the student used the register of engineering in order to complete an engineering design task.

To score the writing prompt for engineering academic language, a systemic functional linguistics approach to assessing student writing as outlined by Matthiessen, Slade, and Macken[2] was used. Writing samples were scored for field context to see how students were interacting with the engineering register and field as the semester progresses. The rubric used for assessing writing samples is shown in Table 3.

Table 3

Engineering Speak Rubric for Writing Sample

Linguistic Feature	Specific Objective	Characteristics of Each Score: 3	2	1	0
General Purpose	Engages in materials selection process for bicycle	Sets up an engineering context Selects materials References the bicycle Uses engineering information Explains their thinking	Sets up an engineering context Selects materials References the bicycle Uses engineering information	Sets up an engineering context Selects materials References the bicycle	Does not fulfill any of purpose from prompt
Field	Information is selected from field	Identifies design requirements Explains and predicts phenomena Discusses material properties Discusses macroscopic and microscopic material behavior Offers design limitations	Identifies design requirements Explains (and predicts) phenomena Identifies and compares material properties Offers design limitations	Identifies design requirements Explains (and predicts) phenomena (Offers design limitations)	Does not engage with information from field

	Use of register, and organization of technical terms within register	Utilizes engineering technical terms at most opportunities Groups like technical terms and shows evidence of knowing which ones are associated with others (taxonomies of technical terms) for most concepts discussed	Utilizes engineering technical terms at about half of opportunities, other times engages in colloquial speak Groups like technical terms and shows evidence of knowing which ones are associated with others for about half of the concepts discussed	Utilizes engineering technical terms rarely, mostly uses colloquial speak Does not, or does not often, show evidence of technical term taxonomies	Does not engage in use of engineering register
	Complexity of field	Uses materials science evidence to support most design claims Compares materials based on properties Connects macroscopic and microscopic aspects of material behavior	Uses materials science evidence to support most design claims Compares materials based on properties	Uses materials science evidence to support some design claims	Does not engage in constructing complex relationship within the field

The range of scores the student could achieve was a maximum of twelve and a minimum of zero. The writing samples were scored for general purpose and field. The general purpose assessed the student's general ability to follow through with the task outlined in the prompt. A score of three represented fulfilment of all requirements of the prompt, while a score of zero represented a response that ignored the prompt. Because field is very broad, it was broken into three categories: (1) use of information from the field, (2) use of engineering register, or technical terms, and (3) the complexity of the use of field. The use of information from the field required the student to draw upon engineering ideas that were relevant to the task. This is different from the use of engineering register which examines the technical terms that might be associated with the task. Therefore, the student could score high on use of information from the field but low on use of the engineering register if they wrote about engineering concepts in everyday, colloquial terms. The complexity of use of the field examined the connections the student made between various concepts within the field. Therefore, the student may have used two concepts like atomic bonding and macroscopic properties, and then drew connections between them to generate an idea. However, while student engagement with the engineering field was being examined for engineering speak proficiency, conceptual correctness was ignored. So, it was possible that the student could score very high on engineering speak (as determined by the rubric) due to using substantial technical language and making many complex connections, yet not be conceptually "correct" in any of the language use or complex connections.

By scoring writing samples for engineering language using the rubric, the student obtained a quantitative score for engineering academic language proficiency. Because the writing prompt was administered three times throughout the semester, this provided opportunities to see change over time for two intervals where the engineering academic language might develop and change.

Student Writing Sample

This paper aims to demonstrate and provide insight as to how engineering academic language proficiency can be quantified. One student's writing samples were scored for the span of a semester. Examples of the student's work and how the writing sample was scored will be discussed. Then the general trends observed over time will be examined and assessed.

The first engineering design task was assigned with homework one. At this point in the semester, the student had been in one class in which families of materials and types of bonds were discussed. Overall, the student engaged in the design task, but did not explore thinking or articulate ideas as a practicing engineer would. This is not unexpected at the start of the course. The student also did not discuss any macro/micro connections or use actual materials science to support design claims. The overall score was a 4. Table 4 details this score and shows evidence from the writing sample showing how the student met proficiencies outlined by the rubric.

The second engineering design task was assigned with homework twelve. At this point in the semester, students had learned about bonding, materials properties, crystal structures, and defects. Overall, the student engaged in the design task, but rarely explored thinking or articulated ideas as a practicing engineer would. The student in this sample again did not discuss any macro/micro connections. Materials science language was used on a few occasions to support design claims, though not in depth. The overall score of this sample was a 5. Table 5 details this score and shows evidence from the writing sample showing how the student met proficiencies outlined by the rubric.

The third engineering design task was assigned with homework sixteen. At this point in the semester, students had learned about bonding, materials properties, crystal structures, defects, materials processing and phase diagrams. Overall, the student engaged in the design task. This time, the student began to explain thinking, though not clearly or fully. The student, again, did not identify limitations associated with the design or use microscopic structure of materials to support macroscopic properties of materials. The student used engineering technical language most of the time, through only showed weak to moderate evidence that those terms were used in correct ways. Materials science language was used on a few occasions to support design claims, though not in depth, lacking comparisons. The overall score of this sample was a 6. Table 6 details the basis for this score and shows evidence from the writing sample how the student met proficiencies outlined by the rubric.

Table 4
Scoring of Student Writing Sample 1

Rubric Objective	Requirements for Maximum Score	Student Evidence from Sample	Score/Explanation
Engages in materials selection for bicycle	Sets up an engineering context Selects materials References the bicycle Uses engineering information Explains their thinking	"For a good mountain bike to perform under extreme conditions, I have arranged a list of materials that make up a mountain bike to handle the varying terrain." "…aluminum-carbon frame…" "…comprised of a polymer…" "…so that the rider does not become fatigued." "…can handle the aggressive abuse of a rider's grip yet still maintain its shape and feel soft…."	2 Does not fully explain thinking
Information is selected from field	Identifies design requirements Explains and predicts phenomena Discusses material properties Discusses macroscopic and microscopic material behavior Offers design limitations	"For a good mountain bike to perform under extreme conditions…" "…can handle the aggressive abuse of a rider's grip yet still maintain its shape and feel soft…."	1 Does not connect macro/micro Does not offer limitations
Use of register, and organization of technical terms within register	Utilizes engineering technical terms at most opportunities Groups like technical terms and shows evidence of knowing which ones are associated with others (taxonomies of technical terms) for most concepts discussed	"… polymer that is ductile…." "…polymeric material…" "…ceramic disc brake…"	1 Uses same limited terms repetitively Does not show ability to classify like terms
Complexity of field	Uses materials science evidence to support most design claims Compares materials based on properties Connects macroscopic and microscopic aspects of material behavior	No evidence of proficiency	0 Does not use technical terms in complex way to enable design task
		TOTAL SCORE	4

Table 5
Scoring of Student Writing Sample 2

Rubric Objective	Requirements for Max. Score	Student Evidence from Sample	Score/Explanation
Engages in materials selection for bicycle	Sets up an engineering context Selects materials References the bicycle Uses engineering information Explains their thinking	"In the selection of bicycle parts I would consider a few factors in the materials selection process." "…should not experience a ductile to brittle transition…"	2 Does not fully explain thinking
Information is selected from field	Identifies design requirements Explains and predicts phenomena Discusses material properties Discusses macroscopic and microscopic material behavior Offers design limitations	"…should be very strong and resilient to hot temperatures…" "…carbon fiber would assist in staying strong while mixing well with aluminum when it comes to staying lightweight…"	1 Does not discuss limitations Does not connect macro/micro
Use of register, and organization of technical terms within register	Utilizes engineering technical terms at most opportunities Groups like technical terms and shows evidence of knowing which ones are associated with others (taxonomies of technical terms) for most concepts discussed	"…ductile to brittle…" "…compose tires of a high grade covalent plus van der waals bonding strength…"	1 Rarely uses technical terms No evidence of proper classification/understanding of terms
Complexity of field	Uses materials science evidence to support most design claims Compares materials based on properties Connects macroscopic and microscopic aspects of material behavior	"…a tungsten filament because it has a very high melting point…"	1 Uses materials science to support a few design claims
		TOTAL SCORE	5

Table 6
Scoring of Student Writing Sample 3

Rubric Objective	Requirements for Maximum Score	Student Evidence from Sample	Score/Explanation
Engages in materials selection for bicycle	Sets up an engineering context Selects materials References the bicycle Uses engineering information Explains their thinking	"Consideration must be taken when designing a bike and for what purpose it will be used." "…be flexible enough to deform enough when needed…"	2 Uses more engineering information Does not fully explain thinking
Information is selected from field	Identifies design requirements Explains and predicts phenomena Discusses material properties Discusses macroscopic and microscopic material behavior Offers design limitations	"…have a very durable frame…" "…perform well in both a tension and compression test." "…have a high modulus." "…can withstand a decent stress and strain…"	1 Does not discuss limitations Does not connect macro/micro
Use of register, and organization of technical terms within register	Utilizes engineering technical terms at most opportunities Groups like technical terms and shows evidence of knowing which ones are associated with others (taxonomies of technical terms) for most concepts discussed	"…tension and compression…" "…have a high modulus…." "…for van der waals forces…" "…tensile tests…"	2 Uses technical terms most of the time Slight evidence of proper classification/understanding of terms
Complexity of field	Uses materials science evidence to support most design claims Compares materials based on properties Connects macroscopic and microscopic aspects of material behavior	"In the selection of tires I would select a polybutadiene polymer that can withstand the rugged terrain and be flexible enough to deform enough when needed."	1 Uses materials science to support a few design claims Does not make comparisons
		TOTAL SCORE	6

As can be seen, the student's scores were similar over all three samples, increasing only by one point for each interval over the semester. Initially, the student had no complexity in their field. This means that, although technical terms were being used, there was little evidence to support a coherent understanding of their meanings and appropriate use. Even as the semester progressed, the student only was slightly improved in this area. Because this skill is most cognitively complex compared to the others, this phenomena is expected. Use of systemic functional linguistics allowed for observing these subtleties.

The student consistently scored a 2 in the area of engaging in the materials selection process. This shows that he was able to understand the context of the engineering design task, however not fully. He lacked in the ability to explain and justify his choices. This, too, is a higher level cognitive skill, which may explain why the student did not progress in this area.

In being able to select information from the field, the student scored a 1 consistently. This showed that he was able to understand that designing a bicycle has specific requirements and actively attempted to address them. He often attempted to explain why certain materials that were chosen were the best choices. However, he neither discussed the macro/micro connection of his choices nor compared them with other options.

The use of the register, or actual technical terminology, increased slightly over the semester. This is to be expected as students are introduced to a broader range of vocabulary as the semester progresses. While the student did use more technical language over time, there was often little evidence that the language was fully understood or used correctly. In fact, on some occasions, it seemed clear that the student was using technical terminology for the sake of using technical terminology and did not understand its meaning.

Overall, by using an SFL framework, it was possible to explore student proficiency in engineering speak. This framework made it apparent that, while this student used slightly more of the engineering register as time progressed, he still lacked complexity of his field. This phenomena is of utmost importance, since it likely has implications for student understanding. Even though this student may "sound like an engineer" the SFL framework shows that he does not yet "think like an engineer." Thus, this research illustrates, that it is possible, by using an SFL framework, to monitor and quantify the proficiency of a student's use of engineering academic language.

Summary and Implications

The purpose of this paper was to determine the potential for quantifying engineering academic language over the course of a semester. The authors found that student engineering academic language was quantifiable and monitored it over a semester long course by using systemic functional linguistics. This framework allowed for observing student changes in academic language proficiency in the context of the course by examining student interactions with the engineering register and how the technical terms of engineering were used to create complete thoughts.

However, future research must been done in the context of engineering which requires students to not only be able use engineering terms and understand natural science concepts, but to also be able to clearly articulate and understand these concepts with respect to engineering design and other applications. Consider the scientific concept of metallic bonding. One student may describe metallic bonding as, “stationary positive ion cores mutually sharing delocalized electrons” while another student may provide the description, “the electrons float around and the positive parts share them.” While referring to similar phenomena, the first description uses language more consistent with scientific norms than the second. However, for engineering language, this is not where the understanding or language ends. Engineering requires that students relate their understanding of the described micro-scale phenomena of materials to the materials' macroscopic properties, processing, and applications. Engineering speak emphasizes these relationships. For example, a student may give a description such as “the delocalized electrons being shared by the stationary positive ion cores suggest applications that may require high electrical conductivity such as those in electronic or semiconductor devices”. This description is an example of engineering speak because normative technical language of materials engineering is used and emphasizes the micro-macro connection between material structure, properties, and applications.

The use of systemic functional linguistics provides a way for instructors to measure engineering academic language proficiency. Instructors can now monitor student use of field and use it as a measure of student learning. This also gives an additional way to assess student writing samples. Not only can instructors assess students' writings with traditional “correct” or “incorrect”, but now they can examine students' ability to accurately use the language of engineering.

Due to the importance of language in the field of engineering, it is imperative to examine what role student engineering language acquisition plays in conceptual understanding. Quantifying engineering academic language proficiency allows for exploring that interaction. An understanding of the language-concept relationship will help answer the questions of whether students who have greater proficiency in speaking and communicating like practicing engineers are more capable of thinking and engaging in engineering design and other activities than those who struggle with acquisition and use of engineering language.

The authors of this paper acknowledge the support of this research by NSF IEECI grant #0836041.

References

1. Gilbert, J. K., Boulter, C. B., & Rutherford, M. (1998). Models in explanations, Part I: Horses for courses? *International Journal of Science Education, 20*(1), 83-97.

2. Matthiessen, C., Slade, D., & Macken, M. (1992). Language in Context: A New Model for Evaluating Student Writing. *Lingustics and Education, 4,* 173-193.

3. Halliday, M. K. (1992). Towards probabilistic interpretations. In E. Ventola (Ed.), *Functional and systematic linguistics* (pp. 39-63). Mouton.

4. Halliday, M. K., & Matthiessen, C. M. (2004). *An introduction to functional grammar* (3rd ed.). London: Arnorld.

5. Lemke, J. L. (1990). Talking science: Language, Learning and Values. Noorwood, NJ: Ablex.

6. Martin, J. R. (2009). Genre and language learning: A social semiotic perspective. *Lingustics and Education, 20,* 10-21.