Using Systemic Functional Linguistics (SFL) to Create an Observation Protocol for Introductory Engineering Courses

Ing. Fabiola G. Rosales Sanchez, Virginia Polytechnic Institute and State University
Dr. Nicole P. Pitterson, Virginia Polytechnic Institute and State University

Nicole is an assistant professor in the Department of Engineering Education at Virginia Tech. Prior to joining VT, Dr. Pitterson was a postdoctoral scholar at Oregon State University. She holds a PhD in Engineering Education from Purdue University and oth

Ms. Karen Dinora Martinez Soto, Virginia Tech

Karen Martinez Soto is a Ph.D. candidate in the Department of Engineering Education at Virginia Tech. She received her B.Sc. in Aerospace Engineering from the University of Oklahoma and her M.Sc. in Aerospace Engineering at Virginia Tech. Her research interests are focused on teaching and assessment for conceptual understanding, curriculum development for the middle years, and student cultural competencies.

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Introduction

Qualitative research often relies on observational data to understand complex phenomena within their natural contexts. Observation protocols are designed as guides for observational data collection and help to focus researchers' attention on the phenomena of interest. In this study, the phenomenon of interest is how language mediates learning in STEM learning environments. Unfortunately, prior observation protocols have not yet focused on this part of classroom behavior.

Systemic Functional Linguistics (SFL) is a comprehensive linguistic framework that places its primary emphasis on the way language operates in communication and how it is used to convey meaning across various social contexts. As part of a larger NSF funded CAREER award, we developed an observation protocol based on the SFL and several other observation protocols used in education such as the Teaching Dimensions Observation Protocol (TDOP) and the Classroom Observation Protocol for Undergraduate STEM (COPUS). This protocol was tested in a pilot study conducted in two introductory electrical engineering classes over a semester. In total nine classes were observed, taught by two different instructors. Through these observations, we were able to identify areas for improvement in the protocol. The resulting protocol, named Language Observation Protocol in Engineering Classrooms (LOPEC), will serve as the first engineering education protocol for examining the role and use of language in a classroom environment.

This paper's main objective is to explain how SFL has been involved in shaping the development of our observation protocol and how our pilot study significantly contributed to the refinement of the observation protocol we had created. This protocol will play a key role in the larger NSF study dedicated to exploring the role of language in introductory engineering courses.

Literature Review

In the social and behavioral sciences, direct observations are considered to be the base or root of all research methods [1], [2]. Their main benefit of observations as a qualitative data collection method is that they allow "for the researcher to see and record firsthand the activities in which research participants are engaged in the context(s) in which these activities happen" [3, p. 160].

Moreover, observations allow researchers to collect data about phenomena that the participants might not be aware of themselves and therefore not be able to discuss in interviews [4]. Observation protocols are developed to focus the researchers' attention on the phenomena of interests. To do this, observation protocols usually have dimensions or categories that break down the possible behaviors that researchers expect to see. These dimensions are built based on the overall focus of the protocol as well as the research theory or framework that guides the study. Observation protocols also have set structures in which behaviors are recorded. They can either be holistic, where the researcher takes field notes after the observation time, or segmented, where the researcher records every instance of a behavior during a set time-interval [5]. Most observation protocols require a final summary of the experience in the way of fieldnotes after the observation is completed. In the context of engineering and STEM education, several observations protocols have been developed to study teaching practices and instructional effectiveness. Below we describe some of the most commonly used observation protocols:

Teaching Dimension Observation Protocol (TDOP). Based on the instructional systems-of-practice framework, the TDOP was developed to observe course planning and classroom instruction [5], [6]. The TDOP is broken down into six dimensions of practice: teaching methods, pedagogical strategies, cognitive demand, student-teacher interactions, student engagement, and instructional technology. Each of these dimensions has between four and 13 individual codes that describe the "actual instructional behaviors that are measured by the TDOP" [6, p. 11]. In terms of the behavior-recording structure, this protocol is segmented in 2-minute intervals.

VaNTH Observation System (VOS). Based on the How People Learn (HPL) theory, the VOS was developed to "capture quantitatively teaching and learning experiences of the bioengineering classroom" [7, p. 329]. The VOS is broken down into four components: classroom interaction observation (CIO), student engagement observation (SEO), narrative notes (NN), and global ratings (GR). Although the VOS is a segmented observation protocol, each one of the four components is observed or recorded at different times during the observation. The first three components are recorded in sequence during the class as follows: 3 minutes CIO, 30 to 60 seconds SEO, and 1 to 2 minutes NN. After the observation is completed, the GR scores and summary for the observation as a whole are recorded [5], [7].

Cooperative Learning Observation Protocol (CLOP) The CLOP was developed based on the five elements of cooperative learning: Positive Interdependence (P), Individual Accountability (I), Group Processing (G), Social Skills (S), and Promotive Interaction (F) [5], [8]. Its primary focus is to "evaluate elements of cooperative learning and taming skills used by students" [5, p. 98]. The CLOP is a segmented protocol which records behaviors of cooperative learning in 5-minute intervals. During each interval, the observer indicates the engagement level of each of the five elements as low, medium, high, or not observed. There are different variations of the CLOP that include designated areas for note taking and task/activity description.

Classroom Observation Protocol for Undergraduate STEM (COPUS) Using the TDOP as a model, the COUPS focuses on recording the allocation of time by both faculty and students during classroom activities [5]. As such, the COPUS is divided into two categories: Students are Doing, and Instructor is Doing [9]. These categories have 13 and 12 codes respectively that describe expected behaviors of the class participants. In terms of the recording structure, this protocol is segmented in 2-minute intervals.

Sheltered Instruction Observation Protocol (SIOP) The SIOP was developed as part of an effort to support second language acquisition in English language learners [10]. Its primary focus is to observe the preparation and delivery of academic content that is comprehensible to students with a different native language. The observation protocol consists of 30 codes divided into eight dimensions: Preparation, Building Background, Comprehensible Input, Strategies, Interaction, Practice/Application, Effectiveness of Lesson Delivery, and Review/Assessment [11]. The SIOP is a holistic protocol that requires the observer to score the sheltered lesson from Not Evident (0), to Highly Evident (4) in the 30 codes at the end of the observation. These scores are summed to form a total SIOP score for the lesson.

Although there are several established observation protocols for engineering classrooms, it is not unusual for a desired focus of observation to be outside of the scope of these established protocols. As such, it is common for new protocols to be developed as the need for a new focus arises. New observation protocols can be developed based on a theoretical framework such as the SIOP and

the CLOP, or they can be adapted from existing protocols, like the COPUS is an adaptation of the TDOP [5].

Theoretical Framework

To develop the observation protocol, we used the Systemic Functional Linguistics (SFL) framework as a foundation. Systemic Functional Linguistics (SFL) is a comprehensive linguistic framework that places its primary emphasis on the way language operates in communication and how it is used to convey meaning across various social contexts. Instead of viewing language as a rigid set of rules, SFL recognizes it as a group of choices that individuals can make when expressing themselves through speech or writing [12]. This framework has been widely used in K-12, where it has been employed to analyze how scientific concepts intersect in classrooms, whether through spoken discourse or written text.

To comprehend language, Systemic Functional Linguistics (SFL) investigates the application of foundational grammar to establish both register and meaning. SFL consists of three main constructs: foundational grammar, register, and meaning. SFL analyzes the components of register, including field, tenor, and mode, as well as the components of meaning, which are ideational, interpersonal, and textual, observing their interaction [13]. For the observation protocol, we have concentrated on the register construct. Register is the context in which language is employed and is divided into three key variables influencing effective language use: field, tenor, and mode [14]. Field pertains to the specific subject or topic of language use, encompassing vocabulary related to that topic and the knowledge and concepts required for effective communication within it. Tenor relates to both the audience being communicated with and the way the message is conveyed, known as mood. It involves the listener and the tone of communication, significantly influencing language and style choices. Mode refers to the means and medium of communication, addressing how the message is transmitted, whether through spoken or written language, and the selection of words, sentence structure, and communication style. Figure 1 summarizes the cyclical relationship between these three variables.

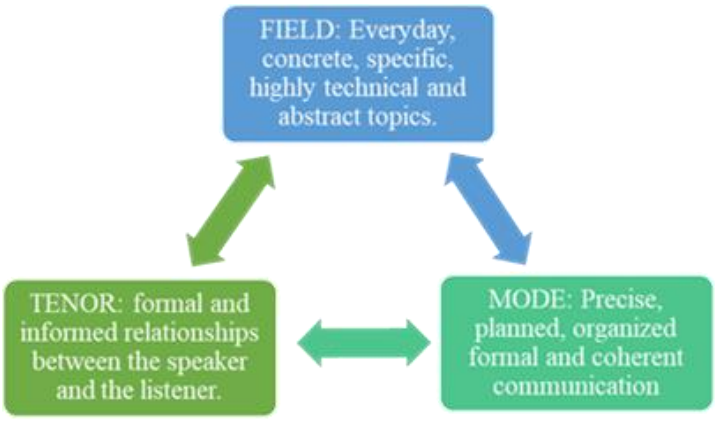

Figure 1 – SFL language variables

Understanding these three variables of Register (field, tenor, and mode) has provided valuable insights into how language is adapted and used across various contexts. This understanding equips us with the tools to identify key aspects during class observations and develop the observation protocol. In the observation protocol, we have emphasized examining the key concepts that professors use and how they explain tasks to address the field. Additionally, we have developed codes to observe students' actions and responses (the audience) and the mood of the professor for certain questions and explanations to address the tenor. Moreover, to address the mode, we have examined the methods the teacher uses for lecturing (such as writing on boards or using PowerPoint) and the techniques employed to clarify content concepts.

Methods

To develop the observation protocol, we initially conducted a compilation of existing observation protocols designed for classes. We reviewed five protocols: Teaching Dimensions Observation Protocol (TDOP), VaNTH Observation System (VOS), Cooperative Learning Observation Protocol (CLOP), Classroom Observation Protocol for Undergraduate STEM (COPUS), and Sheltered Instruction Observation Protocol (SIOP). For each protocol, we carefully examined their categories and corresponding codes. Upon determining our specific observation needs, we identified two relevant categories from COPUS, one from SIOP, and one from TDOP that we could use. These categories focused on monitoring student activities, instructor actions, communication methods used by the instructor, and the dynamics of student-teacher interactions. These elements constituted the primary aspects we intended to observe according to our framework. Following

this, we synthesized these categories into a comprehensive observation protocol comprising four main categories: "Students are doing," "Instructor is doing," "Instructor communication," and "Student-Instructor interaction." The figure below summarizes the process of identifying categories for the resulting protocol.

Figure 2 – Summary of category identification process

Our codes aligned with the Field construct of the SFL framework, addressing instances where the instructor emphasized key vocabulary or connected past and new concepts. Additionally, within the 'instructor-student interaction' category, we included codes for the Tenor construct, specifically noting when the instructor posed rhetorical or comprehensive questions. Codes related to the Mode construct were incorporated in the 'instructor is doing' category, considering activities such as writing on the board, using PowerPoint presentations, and employing scaffolding techniques.

Both the first and second authors tested the protocol using video recordings from two chemical engineering classes. Independently, we observed the same classes to compare our results, and we identified consistent observations. After this initial test, we concluded that the codes were clear for us as the primary researchers. However, recognizing the need for refinement, we decided to introduce two additional codes. In the ‘Instructor communication’ category, we incorporated a code for occurrences where the instructor made a reference to external sources, such as books or webpages. Additionally, we introduced a code for situations where the instructor responded to students' questions, within the ‘Student-instructor interaction’ category. After the initial testing, we recognized the necessity to evaluate the protocol in a real-life setting to observe student interactions. Consequently, we observed three classes from a first-year introductory engineering

course. While the protocol performed effectively, following the first two observations, we identified the need for an additional code in the 'Student-Instructor interaction' category. This new code aimed to capture instances when the instructor empathized with the students on a personal level. After these two testing phases, our observation protocol was finalized for implementation in our pilot study within electrical engineering classes.

The pilot study was conducted at a large research-intensive institution, where we observed both a first-year introductory circuits course and a junior-level electrical engineering course. The choice of these courses for the pilot study was influenced by personal connections one of the authors had with the professors in charge. Starting with the first-year course, we observed a total of five classes. Through these observations, we recognized that certain codes were unnecessary as they were never utilized. Additionally, we introduced a new code in the 'Instructor communication' category, specifically indicating when the instructor defined new concepts, as we observed this to be a regular practice in the introductory course. Moreover, we observed four classes of the junior-level engineering course, during this observation we identified a need for additional codes to highlight different moods in the Tenor construct. Therefore, we added a code for instances when the instructor used humor, a soft tone, or a hard tone. Additionally, we realized that one of the codes, titled 'Techniques for clear content understanding,' needed to be separated into two distinct codes. One for situations when the instructor used techniques like conducting demos and visuals, and another for instances involving body language or gestures.

Results

As a result, we have developed a new observation protocol named the Language Observation Protocol in Engineering Classrooms (LOPEC). We believe that this observation protocol aligns with our requirements for observing an engineering classroom. It is designed to meet the three constructs of Systemic Functional Linguistics (SFL) that we deem important and necessary for comprehending how language contributes to students' conceptual understanding of fundamental engineering concepts. The final protocol is composed of four categories: Students are Doing, Instructor is Doing, Instructor Communication, and Student-Instructor interaction. In Appendix 1, we can see the final protocol with the categories, the codes, and the explanation of each code.

Discussion and Conclusion:

The LOPEC is designed to capture the three variables associated with the register construct of SLF: field, tenor, and mode. To achieve this, the behaviors observed by the LOPEC are divided into four categories: Students are Doing, Instructor is Doing, Instructor Communication, and Student-Teacher Interaction. The Field construct of SFL was represented in codes throughout the four LOPEC categories but was particularly presented in Instructor Communication. This category had codes that pertained to the use of topic specific vocabulary such as “Key Vocabulary Emphasized” and “Defines New Concepts”. SFL theory highlights the importance of reinforcing key vocabulary when introducing students to new concepts. This behavior of reinforcement is also present in the Student-Teacher Interaction category with codes for both instructor and student comprehension questions. Checking for understanding and seeking clarification on topic-specific concepts is an important step in knowledge scaffolding.

The Tenor construct of SFL was also represented in the Student-Instructor Interaction category as it recorded how the communication was happening and which agent of the class was initiating it. Moreover, the Instructor Communication category included codes that focused specifically on the tone of the communication such as “Use of Humor” or “Communicates in a Soft Tone”. It was important to record the tone of the class since it directly affects the relationship between the instructor and the students.

Finally, the Mode construct of SFL was covered by the Students are Doing and Instructor is Doing categories of the LOPEC. These categories focused on how instruction happened, whether via a power point presentation or traditional lecturing. Moreover, by separating the actions between the students and the instructor, these categories allow to record how the same communication is experienced differently by the various participants of the class.

By aligning the codes and categories of a new observation protocol to the tenets of SFL, the LOPEC was designed to be a tool that allows to capture language in a STEM learning environment. This is an important tool in STEM education because it can highlight how the nuances of language affect students' understanding of technical STEM courses. The process of testing the protocol in real-time classroom settings allowed us to discern the aspects that worked and those that required

improvement. Also, this experience permitted us to incorporate codes and variations not initially considered, enriching the depth and breadth of our protocol. Our findings show the significance of collaborating with the participants, in this case, the instructors, in the development of an effective observation protocol. The teaching methods employed by the instructors were influential in detecting the areas requiring refinement in our protocol. Moreover, as a research tool, the LOPEC will facilitate research on ways of leveraging language and classroom communication to develop student's conceptual understanding of technical courses. Finally, this observation protocol was developed as part of a larger NSF funded CAREER award and will serve as a main data collection method for follow-up studies.

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Appendix 1

LOPEC PROTOCOL		
Categories	**Codes**	**Explanation**
Students are Doing	Ind - Working individually	Individual thinking/problem solving
	L - Listening to instructor	Listening to instructor
	Prd - Making a prediction	Making a prediction about the outcome of demo or eperiment
	SP - Presentation by student	Presentation by students
	TQ - Test or quiz	Taking a test or quiz
	W - Waiting	Nobody talking, instructor late, working on fixing AV problems
	WC - Engaged in whole class discussion	Engaged in whole class discussion, often facilitated by instructor
	WG - Working in groups	Working in groups on worksheet activity
	O - Other	
Instructor is Doing	Adm - Administration	Administration (assign homework, return tests, etc)
	LS - Listening to student	Listening to student presentation
	Lec - Lecturing	Lecturing, presenting content
	MG - Moving through class guiding student work	Moving through class guiding ongoing student work during active learning task
	RtW - Real-time writing on board/ipad	Real-time writing on board, iPad, projector, etc
	W - Waiting	Nobody talking
	SOL - Solving class problems	Solving problems on the board or ppt
	LPV - Lecture with pre-made visuals	Lecturing using ppt, projector, etc
	D/V - Showing or conducting a demo	Showing or conducting a demo, experiment, simulation, video, etc
	O - Other	
Instructor communication	CN - Linking concepts to world experiences	Concepts linked to students' background or real world experiences
	CPN - Connecting past and new concepts	Links made between past learning and new concepts
	KVE - Key vocabulary emphasized	e.g. introduced, written, repeated, and highlighted for students to see
	CTE - Clear task explanations	Explanation of academic tasks clear
	TCU - Techniques for clear content understanding	Professors techniques to make content concepts clear (e.g. visuals, gestures body language)
	SSU - Consistent scaffolding for student understanding	Use of scaffoling techniques throughout lesson (e.g. solving problems with the class, think-alouds)
	RS - Reference other sources	References other sources verbal or written
	DEF - Defines new concepts	Explain new concepts for the course
	EMP - Emphatize with students	Speaks empathetically with students and gives examples
	HUM - Use humor	
	SFT - Communicates in a soft tone	
	SRT - Communicates in a strong tone	
Student-instructor interactions	RQ - Instructor rhetorical question	Question does not seek answer
	DQ - Instructor display question	Seeks specific information
	CQ - Instructor comprehension question	Checks for understanding
	SNQ - Student novel question	Seeks new information
	SCQ - Student comprehension question	Seeks clarification of a concept
	SR - Student response	
	FUp - Follow up/feedback	Follow-up/feedback on activity to entire class
	1o1 - One on one extended discussion	One on one extended discussion with one or a few individuals
	IR - Instructor response	