Examining the Literacy Practices of Engineers to Develop a Model of Disciplinary Literacy Instruction for K-12 Engineering (Work in Progress)

Introduction

Efforts to diversify the engineering workforce are informed by the fact that engineering continues to remain a White, male-dominated profession [1]. Underrepresented students leave science, technology, engineering, and mathematics (STEM) programs in middle school, high school, and in undergraduate programs [2]-[4] at a disproportionate rate compared to their White male colleagues.

In order to broaden participation and provide equitable engineering education for underrepresented students, better approaches are necessary to support these students' pathways toward STEM careers. One approach for encouraging diverse participation in engineering is through disciplinary literacy instruction (DLI). Research has shown that implementing DLI in other subjects, such as history, has led to students showing greater mastery of historical thinking, increased ability to transfer historical knowledge to other contexts, and improved reading comprehension compared to peers that did not receive DLI [5], cf. [6], [7]. Similar studies have been conducted in science [8].

Research on disciplinary literacy suggests that use of DLI in engineering may increase students' abilities to engage in engineering thinking as well as lessen literacy-based barriers that prevent women and underrepresented students from pursuing STEM pathways. To accomplish this goal, a robust model of DLI in engineering must be developed and disseminated into K-16 classroom practice.

Background

This paper describes NSF-funded work based on a promising approach for encouraging and supporting diverse participation in engineering: disciplinary literacy instruction (DLI). Disciplinary literacy refers to how strategies for reading and writing are used in discipline-specific contexts [9]. Being literate in a discipline commands an understanding of how information is created, shared, and evaluated [10]. The term "literacy practice" is drawn from the definition of "literacy event" purported by Heath [11]. Heath [11] defined literacy events as "occasions in which written language is integral to the nature of participants' interactions and their interpretive processes and strategies" (p. 50). Further research indicates that members of a social group engage in patterned types of literacy events -- literacy practices -- while working together to solve problems [12].

Models of DLI have been previously developed from analyzing literacy practices of professional practitioners, in fields such as history [13], [14], and translating these practices into academic DLI materials for K-12 students. For example, Wineburg studied the thought processes of

historians and his research was used to develop the Stanford History Education Group (SHEG, https://sheg.stanford.edu/), a website that provides DLI curricula for K-12 students that teach students to read like historians. Instruction based around these authentic practices allows students to develop an understanding of how experts read and generate texts to solve problems or communicate information. This is done by apprenticing students in interpreting, producing, and evaluating discipline-specific texts in ways that reflect practices utilized by experts in the field. It has been shown that teachers can use DLI to provide K-12 students with a framework for interpreting, evaluating, and generating discipline-specific texts. Students who receive DLI and learn to "read like" professional practitioners performed better on various outcome measures compared to students that did not have DLI [5], cf. [6], [7], [15], [16]. The findings emerging from these studies suggests that DLI improves both women and minority student performance [16] in a variety of disciplines, and thus encourages research on DLI to improve student outcomes in K-16 engineering education.

Disciplinary literacy instruction aims to ensure that all students, especially those from underrepresented groups and those with diverse cultural backgrounds, have access to challenging discipline-specific concepts. Research has shown that children from underrepresented groups, such as African Americans, Native Americans, and Latinas/os, are less likely to develop an understanding of literacy practices in technical fields compared to children from White, middle class families [17]. Archer and colleagues, for example, found that children from White and Asian families were more likely to read and engage with scientific texts at home compared to working class families from underrepresented groups [18], cf. [19], [20]. Their findings indicate that White and Asian children develop an understanding of STEM literacy practices at an early age, while members of underrepresented groups often feel a lack of familiarity with STEM practices. Therefore, it is theorized that women and members of underrepresented groups must be exposed to authentic literacy practices of various technical disciplines, including engineering, to improve participation and representation in the technical workforce. In order to encourage participation in these technical fields, Gee [17] argued that underrepresented groups must be explicitly taught the literacy practices of these disciplines.

Additionally, students that are successful in a particular discipline are more likely to pursue that discipline in the future [21]. DLI can be used to improve academic performance of women and underrepresented students and encourage them to pursue technical pathways.

Research Goals
While models of disciplinary literacy have been developed and disseminated in several humanities and science fields [10], little research on disciplinary literacy has been conducted in the engineering domain. This research project aims to address this gap by developing and disseminating a model of disciplinary literacy in engineering. This model will draw upon experiences and literacy practices performed by engineers in the engineering workplace.

Engineering literacy practices include how engineers read, evaluate, interpret, synthesize, and communicate information within their workplace. The DLI model will represent the practices used by engineers, working across multiple sub-disciplines, as they read and analyze disciplinary specific information. These engineers will be responding to different sets of goals and communicating across a variety of audiences at their respective companies. The data obtained from analyzing engineers in diverse activities throughout this study will provide a robust, cohesive model of literacy practices utilized across the engineering domain.

A model of disciplinary literacy in engineering will be useful for those working with elementary, middle school, high school, and undergraduate students because it will provide students with ways to understand and engage with authentic engineering literacy practices. With this model, K-16 students will develop the necessary strategies to think like engineers as they engage with engineering texts and in design activities. These strategies will positively help students understand complex engineering topics. This foundation for DLI in engineering will help improve participation from minority and underrepresented groups by removing potential literacy-based barriers that previously prevented them from identifying with and engaging in engineering disciplines. As students become more familiar with literacy practices used by engineers, they will begin to understand how engineers think through and solve problems. DLI will thus equip underrepresented students with the skills necessary to engage with engineering topics and provide a pathway for them to pursue engineering careers in the future.

As a result, the incorporation of DLI in engineering can promote participation from underrepresented groups by encouraging them to be involved in engineering communities, and provides an avenue for these groups to pursue engineering careers in the future. While there are many different approaches to increasing diversity in engineering, we hope the results obtained from this DLI project will lead to more equitable participation in engineering disciplines and a more diversified engineering workforce.

Research Design
For this research, engineers are considered as a social group. Engineers across various sub-disciplines (e.g. electrical, mechanical, civil) use literacy practices as they work together to solve problems and interpret solutions. This project aims to study how engineers use literacy practices to solve problems, and how these practices vary across different sub-disciplines of engineering. Two engineers from four sub-disciplines of engineering (aerospace/mechanical, biological, civil/environmental, and electrical/computer) will be recruited to participate in our study. These sub-disciplines were selected because they are the most common areas for undergraduate engineering programs and they are in demand nationally [22], [23]. The results obtained from these sub-disciplines can then be broadened to a more general model of disciplinary literacy in engineering.

This project uses a multiple comparative case study design in order to compare and contrast literacy practices across engineering disciplines. Data is collected from one sub-discipline at a time and then compared across disciplines. We will collect data from two engineers from each sub-discipline over the course of six months. During this time, four types of data will be generated with each of the two engineers: Transcripts from current or retrospective protocols (collected once per month) and field notes from observations (collected three times per month).

Current and retrospective protocols, also known as think-alouds, are commonly used in studies assessing disciplinary literacy and engineering design thinking [24], [10], [25], [26]. During current protocol sessions, engineers "think aloud" while creating or interpreting texts in the moment. In retrospective protocols, the engineers describe what they were thinking while creating a particular text in the past, while having the text in front of them as they are speaking. Observations may be audio and video recorded. If recording is not allowed during the observations, the research team will take detailed field notes that capture the kinds of literacy practices used by the engineers. The results obtained from these observations will help research team determine the cognitive frameworks that shape the engineers' literacy practices.

Three types of artifacts are being collected from the engineers that will serve as the basis for the think-aloud protocols. These include a daily log of literacy practices, texts that the engineers read, and texts that the engineers write. Semi-structured interviews are conducted once per month. These consist of a set of questions generated from reviewing the collected artifacts and observation field notes. Questions may also be modified from previous interview protocols. These interviews highlight the cognitive frameworks that guide the engineers' literacy practices across various texts and in a variety of situations as they work on tasks in the workplace. Transcripts from interviews, observations, and think-alouds are analyzed using constant comparative analytic (CCA) methods.

Preliminary findings
From the preliminary set of data from the two electrical engineers, several types of codes are emerging. The codes show that electrical engineers engage with textual genres such as emails, software code outputs, and technical specification documents. The coded data also reveal that the engineers work with multiple texts at a time. For example, an engineer read a data sheet for an electronic device in one window of their computer, while another open window consisted of a table describing technical specifications for another device.

Additionally, the coded data show that engineers work on their computers both individually and collaboratively in order to analyze texts and solve problems. For example, an engineer collaborated with a coworker on debugging a software code in one of their offices. They were

both looking at the same software code on the same computer screen, discussing ideas and making changes together as they worked to understand the problem with the software code.

The preliminary data also indicate that engineers have different purposes for reading and writing texts. Some of these purposes include analyzing errors, documenting activity, fixing errors, obtaining technical information, and recording test results. When engineers read error messages or debugging results on software code output, for example, they are reading to analyze the errors in their software code.

Implications for K-12

The preliminary results from this study provide several implications for implementing DLI in K-12 settings. The results suggest that students benefit from learning to read a range of texts, such as data sheets, technical specification documents, and software code output. Additionally, students should learn to discuss these texts with others and justify their reasoning for writing or interpreting a text a certain way. Students should also be taught how to read or create texts for certain purposes to convey information or accomplish a task.

Summary

The preliminary data collected from the two electrical engineers will be combined with data from engineers in other sub-disciplines to form the foundation of the model of disciplinary literacy instruction in engineering. The data obtained from this research will result in texts, evaluative frameworks, and a set of authentic practices that K-12 teachers can use to support a diverse body of students in learning to think and problem-solve like engineers.

References

[1] National Science Board. (2016). *Science and engineering indicators 2016.* Arlington, VA: National Science Foundation (NSB-2016-1).

[2] Tai, R. T., Liu, C. Q., Maltese, A. V., & Fan, X. T. (2006). Planning early for careers in science. *Science, 312,* 1143-1144.

[3] Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation, and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching, 47,* 564-582.

[4] Hernandez, P. R., Schultz, P. W., Estrada, M., Woodcock, A., & Chance, R. C. (2013). Sustaining optimal motivation: A longitudinal analysis of interventions to broaden participation of underrepresented students in STEM. *Journal of Educational Psychology, 105,* 89-107.

[5] Reisman, A. (2012). Reading like a historian: A document-based history curriculum intervention in urban high schools. *Cognition and Instruction, 30*(1), 86-112.

[6] de la Paz, S. (2005). Effects of historical reasoning instruction and writing strategy mastery in culturally and academically diverse middle school classrooms. *Journal of Educational Psychology, 97,* 139-156.

[7] Monte-Sano, C., & De La Paz, S. (2012). Using writing tasks to elicit adolescents' historical reasoning. *Journal of Literacy Research, 44,* 273-299.

[8] Cervetti, G. N., & Pearson, P. D. (2012). Reading, writing, and thinking like a scientist. *Journal of Adolescent & Adult Literacy, 55,* 580-586.

[9] Chauvin, R., & Theodore, K. (2015). Teaching content-area literacy and disciplinary literacy. *SEDL Insights, 3*(1), 1-10.

[10] Shanahan, C., Shanahan, T., & Misischia, C. (2011). Analysis of expert readers in three disciplines: History, mathematics, and chemistry. *Journal of Literacy Research, 43,* 393-424.

[11] Heath, S. B. (1982). What no bedtime story means: Narrative skills at home and school. *Language in Society, 11,* 49-76.

[12] Street, B. V. (2000). Literacy events and literacy practices: Theory and practice in the New Literacy Studies. In K. Jones & M. Martin-Jones (Eds.), *Multilingual literacies. Reading and writing different worlds* (pp. 17-29). Philadelphia: John Benjamins Publishing Company.

[13] Wineburg, S. (1991). Historical problem solving: A study of the cognitive processes used in the evaluation of documentary and pictorial evidence. *Journal of Educational Psychology, 83*(1), 73-87.

[14] Wineburg, S. (1998). Reading Abraham Lincoln: An expert/expert study in the interpretation of historical texts. *Cognitive Science, 22,* 319-346.

[15] Kelly, G. J., Chen, C., & Prothero, W. (2000). The epistemological framing of a discipline: Writing science in university oceanography. *Journal of Research in Science Teaching, 37,* 691-718.

[16] Cervetti, G. N., Barber, J., Dorph, R., Pearson, P. D., & Goldschmidt, P. G. (2012). The impact of an integrated approach to science and literacy in elementary school classrooms. *Journal of Research in Science Teaching, 49,* 631-658.

[17] Gee, J. P. (2015). *Social linguistics and literacies: Ideology in discourses* (5th ed.). London, UK: Routledge.

[18] Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science. *American Educational Research Journal, 49,* 881-908.

[19] Archer, L., Dawson, E., DeWitt, J., Seakins, A., & Wong, B. (2015). "Science capital": A conceptual, methodological, and empirical argument for extending Bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching, 52,* 922-948.

[20] Archer, L., DeWitt, J., & Osborne, J. (2015). Is science for us? Black students' and parents' views of science and science careers. *Science Education, 99,* 199-237.

[21] Eccles, J. S. (2005). Subjective task value and the Eccles et al. model of achievement related choices. In A. J. Elliot & C. S. Dweck (Eds.), *Handbook of competence and motivation* (pp. 105-121). New York, NY: Guilford Press.

[22] Bureau of Labor Statistics. (2016). *OES research estimates by state and industry.* Retrieved from: http://www.bls.gov/oes/current/oes_research_estimates.htm

[23] National Center for Educational Statistics. (2013). *Bachelor's, master's, and doctor's degrees conferred by postsecondary institutions, by sex of student and discipline division: 2011-2012.* Retrieved from: https://nces.ed.gov/programs/digest/d13/tables/dt13_318.30.asp

[24] Rainey, E. C. (2016). Disciplinary literacy in English Language Arts: Exploring the social and problem-based nature of literary reading and reasoning. *Reading Research Quarterly.* Published online first: doi:10.1002/rrq.154

[25] Warren, J. E. (2006). Literary scholars processing poetry and constructing arguments. *Written Communication, 23,* 202-226.

[26] Atman C. J., & Bursic, K. M. (1998). Verbal protocol analysis as a method to document engineering student design processes. *Journal of Engineering Education, 87,* 121-132.