Middle School Engineering Teachers' Literacy Instruction (Fundamental)

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Fundamental: Middle School Engineering Teachers' Literacy Instruction

People enter and exit science, technology, engineering, and mathematics (STEM) pathways at different points in their educational trajectories (Cannady, Greenwald, & Harris, 2014; Maltese, Melki, & Wiebke, 2014), but middle school is an especially critical juncture for capturing and maintaining youths' interest in STEM fields. From fifth to eighth grade, adolescents' interest in STEM often declines (Gonzales et al., 2008; Osborne, Simon, & Collins, 2003), and many develop a negative sense of self-efficacy regarding their potential to succeed in future STEM courses (Chen & Usher, 2013). Though many people exit STEM pathways before they enter high school, this problem is especially pronounced among underrepresented youth who often decide from an early age that STEM careers are not "for me" (Riegle-Crumb, Moore, & Ramos-Wanda, 2011).

To address this problem, educators and researchers have designed many instructional approaches intended to inspire young adolescents to pursue STEM careers. In the discipline of science, one especially promising approach has been literacy-infused instruction, which increases adolescents' understandings of scientific principles (Hand, Wallace, & Yang, 2004; Romance & Vitale, 1992: Spence, Yore, & Williams, 1999) with even greater effect sizes for underrepresented populations (Cervetti, Barber, Dorph, Pearson, & Goldschmidt, 2012; Chen, Hand, & McDowell, 2013; Greenleaf et al., 2011). Experiences with success, in turn, build middle school students' self-efficacy and their desire to enroll in STEM courses in the future (Britner & Pajares, 2006).

Although literacy-infused instruction leads to positive outcomes in science, little research exists on how comparable practices might be implemented in middle school engineering courses. The purposes of this research was to provide ongoing professional development for middle school technology and engineering (TE) teachers on the infusion of literacy instruction and to identify whether and how they infused literacy instruction in the context of their own teaching.

Literacy Instruction

Research on literacy instruction (e.g., Christenbury, Bomer, & Smagorinsky, 2009) suggests that literacy-based supports are not just for early elementary students who are learning to read and write; on the contrary, secondary students and even adults can benefit from literacy supports in different academic disciplines. In this study, we define *literacy supports* including the following elements:

- Students practice reading **comprehension strategies** (Authors, 2014), such as making inferences and asking clarifying questions, as they read multi-representational texts embedded within the engineering design challenges (e.g., clients' descriptions of the problem with photographs);

- **Vocabulary instruction**, including student-friendly definitions, multiple contextualized encounters with target vocabulary words, and discussion of cognates (e.g., aeroespacial in Spanish and aerospace in English) (Graves, August, & Mancilla-Martinez, 2013);

• **Writing scaffolds,** such as graphic organizers or discussing exemplar texts prior to writing (Graham & Perin, 2007);

• **Principled text selection**, including texts with multiple representations, bilingual texts, high-interest texts, and texts that introduce locally relevant design challenges in order to maintain students' interest in the design challenge (Authors, in press).

At its best, literacy instruction can build diverse students' understandings of, and interest in, challenging technical information that is often a part of engineering fields. Thus literacy instruction holds the potential for expanding participation in engineering, especially among youth who are still learning to speak English, by scaffolding and advancing their access to unfamiliar terms and challenging concepts.

Description of the Study

Although literacy instruction may lead to positive learning outcomes in engineering, more research is needed on how TE teachers conceptualize and implement literacy instruction as they participate in professional development on literacy instruction, in order to illuminate the factors that encourage or discourage TE teachers from providing literacy instruction. Accordingly, the purpose of this comparative case study was to identify the literacy-related perceptions and practices of two middle school TE teachers, both of whom taught English learners, as they participated in a year-long professional development on literacy-infused engineering instruction. Specifically, the professional development used a coaching model to support teachers in providing comprehension instruction on relevant texts (e.g., bilingual texts introducing the criteria and constraints of the design challenge) as well as providing writing supports (e.g., mentor texts that students could use as exemplars for their own writing). Consistent with other literacy coaching models (Elish-Piper, L'Allier, Manderino, Di Domenico, 2016), this model included a "coach" who modeled literacy instruction with students, followed by a debriefing between the teacher and coach regarding what went well and what should be modified. The teacher then tried literacy instruction and debriefed them with the coach, with an emphasis on iterative improvement after reflection and with an emphasis on building collaborative relationships.

Data for this study included observations, conducted periodically throughout the school year, as well as monthly interviews with each teacher regarding their perceptions and practices of literacy instruction. Two researchers analyzed the data using inductive constant comparative analytic methods. Specifically, they inductively developed codes from the interviews, such as codes related to the teacher's perception of literacy. The research team then inductively developed codes from the teachers' literacy instruction. The research team then compared the codes from the interviews with the codes from the observations to identify the ways in which the teachers' instruction aligned or did not align with their perceptions and beliefs about literacy and literacy instruction.

Findings

Perceptions of Reading

Both of the teachers observed in this study had multiple years of experience teaching College

and Career Awareness, course designed to introduce (among other things) technical and engineering thinking. Both of the teachers described below have differing perceptions of reading which are related to the activities, units, and practices they emphasized in their instruction. Additionally, both teachers' perceptions are partially based on their school culture and previous teaching experience. While one teacher's perceptions and practices were largely tied to the comprehension instruction given to the whole school, the other teacher viewed reading as a practice tied to engineering thinking.

Teacher one. Allen viewed reading as decoding and breaking down texts. He emphasized reading as an independent practice with a focus on understanding. In interviews throughout the study, Allen mentioned annotations as an important component of reading to understand. He emphasized using the same methods of annotation that students had used in school-wide literacy approaches such as question marks for places they have questions.

Additionally, this teacher focused on comprehension as the main goal of reading such as identifying the main idea, rereading texts, and identifying unfamiliar words. For example, in discussing the role of reading in the engineering design process, Allen responded, "I find it challenging for me to meet the needs of individual reading levels." He saw his role as a teacher to

> *take a challenging text, just one, and to help them break it down at their levels, whereas a student might have 30 words they don't know, and another student may have five words they don't know. The process is the same. Identify the words you don't know, ask questions, find out your answers, and then you'll be able to comprehend the text.*

Allen's view of reading was closely tied to the school culture of improving literacy. He repeatedly referred to practices he had learned during professional development such as annotations, rereading, and vocabulary instruction. As part of the professional development in reading, Allen's school also used time during homeroom to engage students in practicing content-area literacy such as using academic language, note-taking, and identifying text features.

> *We teach them how to approach a new text, the first read through. They're identifying the type of text it is, informational or persuasive, attached to an issue, and then annotation skills, then reviewing annotations in order to make comments and ask questions. We use the Cornell note system. We're breaking down random articles, articles that they might see in any subject area. Then we're preparing them to respond to text, and to speak academically.*

Allen saw value in referring back to these skills during his own class time as he engaged students with texts. He provided this example of incorporating the reading skills from homeroom into an engineering unit:

> *Today, when we were introducing the handout with an aeronautical engineer, they had a paragraph at the start. I challenged them to annotate. It's not something where I need to say, "This is how you annotate." I say, "Do you remember in Trojan time we annotate? We use the same symbols." Then when we meet again, I can refer back to*

> *that reading and say, "Do you have any questions or comments? Unfamiliar words? What do you think is most important about it?" If they've annotated, they're not starting from the beginning. They're starting from maybe a re-read.*

Additionally, Allen emphasized the importance of vocabulary as essential to comprehension, especially for students learning English as an additional language. Allen often provided examples of asking students to identify unfamiliar words. He also noted unfamiliar words as a barrier to comprehension. Allen noted vocabulary instruction as an area he wanted to improve in his instruction.

> *The responsibility has been primarily on the students to identify unfamiliar words, and to participate in class, to make me aware. The limitation to that has been if their students aren't asking questions, then I might hit a few of those. I might point to a few of them that I think they would definitely need to know. The curriculum would benefit from identifying the needed vocabulary and terms in advance. We could anticipate some of the needs of the students, literally.*

As a whole, Allen viewed reading as something that was decontextualized from engineering and design practices. Informing this view is a focus on transferrable reading skills that can be used for texts in contexts other than engineering.

Teacher two. Don saw reading and writing as integral components of the engineering process. Teacher two repeatedly mentioned real world or authentic experiences and saw reading as related to those experiences. He offered examples from his career where he helped students connect to novels through experience.

> *One of the books was a guy, the Paulsen, Gary Paulsen, a lot of his books are easy to follow along and have those same types of experiences. So we talked about going into the airplane, we took them to the airport, and climbed in a plane, and we made arrangements to get in that plane and look around and we didn't fly it but we got in it.*

Because of this emphasis on connecting reading and experience, Don also saw reading as understanding diverse texts. In discussing what he wanted his students to learn in a unit on redesigning a parking lot, he noted many skills of interpreting nontraditional texts.

> *Well I'd like for them to be able to interpret the GIS information…. I'd like for them to get used to looking at aerial photos, because when we look at aerial photos I go where's the best place to build the new communities and they'll pick the sewer lagoons, you know the new soccer fields that are at the west of the town, they don't understand that's water and then it's space limitations and those types of things…The way to understand it is to break it down, and that's what we are trying to do is break it down into small, to understand the concepts, and then expand that out.*

Like Allen, Don noted the importance of helping students break down texts. Unlike Allen, he saw disciplinary texts as essential to solving problems, specifically engineering problems.

> *And really what I'm trying to do is get students to think about if I don't give them all*

the answers, how do they go find it? And then what is the process to developing and finding answers.

Reading for Don is a tool in learning and engaging in authentic practices in a social way. Don often mentioned the importance of having students discuss and plan together as a team, indicating social view of reading. Additionally, he often focused on community members and motivating students to engage in activities that apply to them and their lives.

Practices of Reading

Both teachers incorporated engineering design thinking into their units, emphasizing problem solving and helping students design solutions for those problems. The teachers differed in the ways they incorporated reading into these units. Allen, viewing reading as an independent set of transferrable skills, focused on giving students strategies and practices to ensure comprehension of mostly informational texts. Don, viewing reading as a social practice connected to authentic experiences, emphasized practices that helped students connect reading of traditional and non-traditional texts to the solution of a problem.

Teacher one. In observing two units, Allen engaged in reading practices aligned with his view of reading. The most common literacy instruction in Allen's classroom was vocabulary instruction. This instruction appeared both as preplanned instruction as well as responses to students' questions about vocabulary. Allen used a variety of vocabulary instruction, especially for the pre-planned vocabulary. For example, the teacher asked students to break apart the word aerospace and use the parts to guess the meaning. The teacher also used analogies, telling students stories to help them remember words. Allen mentioned these stories as an effective teaching strategy, especially for students who were learning English. In addition to these methods, the teacher also had students identify words they didn't know as they read a text. In these cases, the teacher defined the words for the students, offering student friendly definitions.

Allen asked students to read and annotate texts once in these units. Students generally engaged in reading individually. Allen asked students to discuss their reading once. This student discussion was primarily concerned with sharing a question with another student. The teacher stopped the discussion after 30 seconds. Allen's reading practices seem to match his view of the purpose of reading: to gain information. Students were engaged in making meaning from the texts and they practiced strategies to improve comprehension and understanding. In these two units, students did not use the information they read and were not asked to read with an engineering purpose in mind such as identifying the problem.

Allen's texts seemed informational in nature. In one unit, students were asked to design and test a model airplane. Students learned many new vocabulary words such as aerospace engineer, tapered leading edge, and straight trailing edge. As students designed their planes, they didn't apply these words or use them to share the results of their design. Allen used vocabulary to increase comprehension of texts. Though students used these components in their design, the use of the vocabulary was not specifically related to the decisions the students made with their designs.

Teacher two. Don's reading practices reflected his view of literacy as an action tied to an authentic practice. Don included multiple practices of comprehension instruction as well as disciplinary literacy practices. These practices were mostly associated with identifying the problem as students planned for their design.

In a unit on redesigning a parking lot, Don had students read an aerial map of the parking lot. He then led them outside and had them use their map as they walked around the parking lot, noting the symbols and signs the students saw. As Don engaged students in reading the map, he guided their comprehension with questions focused on the problem the students would be addressing in their designs. For example, the discussion below occurred as the teacher led the students to points on the map, directing the discussion towards interpreting the symbols in terms of the engineering project.

Don: Point where we are at right now. We are here. Now we are going to walk towards

Point B. So let's walk out to Point B. Okay why is Point D even on here? Why do we have Point D? This is pedestrian traffic flow right? Do we have any places marked for pedestrians on the parking area?

Students: No.

Don: Do we have places for cars to park?

Students: Yes.

Don: How do you know?
Students: Because there's
lines.

Don: Because there are lines okay. Can that be part of your solution?

This example was characteristic of the discussions the teacher had with students as a whole class. The teacher led students to make meaning from non-traditional texts, guiding students to think about each text as engineers.

Don gave students a purpose in reading texts closely aligned to the stage in the engineering cycle the students were practicing. For example, as the students engaged in identifying the problem, they were given a handout to read with these instructions "During the reading, you are acting as a civil engineer. You want to decide what information's important in that reading. Highlight it."

While Don used some of the same strategies as Allen, such as highlighting and annotating, his instructions were closely tied to the problem students were trying to solve. Rather than framing the reading as a way to comprehend information, Allen framed the reading as a way to use information. Table 1 summarizes both teachers' reading perceptions and practices.

Table 1
Perceptions and Practices of Reading

	Allen	Don
Definition of reading	Independent practice of decoding traditional texts	Social practice of making meaning from traditional and non-traditional texts
Purposes of reading in engineering	Identify the main idea Improve academic language and texts (e.g. text-features) Improve reading skills so they transfer to other content areas	Connect information to experience Solve problems Synthesize information from multiple texts to develop answers
Practices of reading in engineering	Annotating to make comments and ask questions Frontloading vocabulary instruction using word-parts or analogies Rereading texts Identifying difficult vocabulary during reading	Identify the problem presented in a text Guiding questions Identify information most important to an engineer Partner reading and discussion
Types of texts	Informational text about forensics Informational text about Aeronautical engineers	Case-Study of parking-lot problems Aerial Maps Parking Lot (including traffic signs)

Perceptions of Writing

Both teachers incorporated a writing component into their instruction, especially emphasizing the importance of writing in idea generation. While both teachers viewed writing as clearly connected to the process of engineering, one teacher focused much more on writing as an informal practice without incorporating writing as a way to share ideas.

Teacher one. Contrary to reading, Allen viewed writing as central to the engineering design process. He repeatedly mentioned the use of engineering notebooks in the interview process. He emphasized the importance of brainstorming, documenting observations, and revisiting those notes. He noted that he wanted to rely more on using the notebook as a place to gather ideas and record data. Unlike his view of reading, Allen saw writing as something engineers do, and he wanted to share that with students.

> *I want my students to appreciate the for example that engineers are writers. Yes, we're going to be making things but we also need to describe what we're about to do and report on what we've just accomplished*

Allen did not see writing as a formal process, but as a documentary one. He did not mention communicating results when asked about the role of writing in engineering. He also did not mention writing for an audience. Allen did see writing as multi-modal. He frequently mentioned that he wanted students to include drawings, labels, and measurements with their

writing.

Teacher 2. Don viewed writing in a similar way to reading. He saw writing as integrated into real practices of engineering. When asked about the role of writing in engineering, he focused on idea generation rather than spelling or punctuation. In his comment below, Don described his grading practices as related to ideas, emphasizing the real-world use of writing in engineering.

> *We have a journal and I'll check the journals off, but I'm not going to grade it on punctuation, I'm not going to grade it on spelling, I'm not going to grade it on, it's going to be on the general ideas that are captured. So those are integral parts of the engineering component. When working in the real-world environment, when you are sitting down at the table and brainstorming, you're writing things down, you know writing down those ideas.*

Don also saw writing as a finished project, but felt less prepared in helping students communicate their ideas as a final project or presentation. In evaluating the writing component of his lesson, Don mentioned, "I don't know how to teach writing. I don't have a clue. I'm not trained in that. But more of these types of activities come through, I'm learning more."

Don also saw writing as collaborative. In brainstorming ideas, he mentioned that engineers share their brainstorms and journaling as a team. Later on, in thinking about helping students improve their writing, he suggested have students collaborate on one part of the draft and work on redrafting individually. He also mentioned peer-editing as a way to help students improve.

Practices of Writing

Compared to reading instruction, both teachers' practices did not directly relate to their perceptions of writing instruction. In the case of the first teacher, the writing activities he included as well as multiple instructional practices to improve student writing were closely tied to his belief of the importance of writing as generating and revising ideas. For the second teacher, however, though the teacher emphasized the importance of collaborative brainstorming and presentation of ideas, his writing activities were primarily assigned without strategies to help students complete these tasks.

Teacher One. Allen provided multiple opportunities for students to engage in disciplinary writing instruction. Students in this class were given a notebook where they were encouraged to keep track of brainstorms, observations, and reflections. For example, after having students test their designs of an airplane, the teacher instructed the students to write down two observations from the test in their notebooks. Additionally, the teacher directed students to evaluate their designs according to criteria for the project. As students wrote, the teacher asked questions like "Did your design meet the criteria? What was the criteria for distance?" Allen followed these questions with, "the implied question in there is why do you think it did?" The teacher's use of engineering notebooks aligned with his view of engineers as writers. He especially emphasized using the notebook to document results from tests. Allen also asked students to include multiple representations in their notebooks. Along with the evaluation of the students' planes, the teacher instructed students to include drawings of the wings.

Allen also provided direct instruction for student writing including thinking aloud while he modeled his own process for brainstorming. Allen emphasized side views and front views as he modeled brainstorming a design for a chair. He also showed students how he included labels with his design brainstorm. The students in Allen's classroom were frequently engaged in writing processes directly linked to the design process. In contrast to instruction on reading, Allen used writing as a tool in the process of engineering and not on writing as a distinct skill.

Teacher 2. Don gave students opportunities to brainstorm ideas for their projects. In generating ideas for designs, he had students use multiple modes of representation, relying on a computer program to help students create legends for their designs. Don modeled how to create these designs.

Don also assigned students to communicate their results. Don provided them with rubrics to help students know how he would grade their writing. In one instance, the teacher indicated elements that should be included in the writing project. Don relied heavily on Canvas, a cloud-based learning management system, rather than instruction in class to provide writing instruction. He noted that providing examples for students on Canvas for them to refer to would improve instruction, but did not intend to "take any teaching time or any class-time." Don's practices of writing tended to emphasize the idea generation element of writing, rather than a writing as a product. Table 2 summarizes the writing perceptions and practices of the two teachers.

Table 2
Perceptions and Practices of Writing

	Allen	Don
Definitions of Writing	Multi-modal, informal practice to document ideas and observations.	Formal and informal practice to generate ideas and present ideas.
Purposes of writing in engineering	Brainstorm solutions	Collaboratively brainstorm ideas
	Document observations	Present a finalized design
	Record ideas to use for future designs	
Practices of writing in engineering	Engineering notebooks with images, labels, and words	Model elements of a writing component
	Models of brainstorms	Rubrics with important writing components
	Guiding questions for self-evaluation	Assigned presentations
	Think-aloud writing process	

Discussion

Even though the two teachers participated in essentially identical professional development through coaching, they enacted literacy instruction in distinct ways. The first teacher saw

reading as an individual act and as a decontextualized skill that could be applied to any situation. Thus he taught decontextualized skills, such as annotating a text and asking questions, which was a generic skill that could be applied to any context. The second teacher, by contrast, envisioned reading as a more social act that was embedded within the engineering design process. This view influenced how he taught the reading of multiple texts in order to develop solutions to problems. We argue that the second view, reading as essential to engineering, is more aligned with the work of real engineers (Tenopir & King, 2004) and more conducive to discussions and practices that have the potential to lead to rich engineering design activity (Authors, 2017).

In summary, in accordance with this perception of literacy, Allen tended to ask students to annotate and write texts individually, and without discussing with others. By contrast, Don viewed literacy as meaning-making that was integral to (not distinct from) engineering. This teacher considered literacy to include interpreting and producing multi-representational texts. Accordingly, this teacher focused instead on group discussions of diverse texts, such as different solutions to engineering design challenges. Students in this second class had more opportunities to share complex, multi-faceted design-related ideas.

Implications

This study indicates that PD in literacy instruction can seek to foster a broader view of literacy--including the discussion of multimodal texts that are integral to (not distinct from) the design process--in order to foster teacher perceptions of literacy that map onto intellectually rich engineering practices. Thus professional development might not only model for engineering teachers how to provide literacy instruction, but also provide them with opportunities to reflect on their own definitions of literacy as it intersects with engineering. For example, professional development might also provide teachers with vignettes of how engineers use situated reading and writing activities, and ask teachers to reflect on whether and how these uses might be modified and reflected in their own classrooms. Ultimately, we envision engineering education in which linguistically diverse students are supported in understanding and generating complex information and ideas.

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