Supporting Teachers' Science and Disciplinary Literacy Formative Assessment Practices Through the Analysis of Think-Alouds

The Next Generation Science Standards (NGSS) propose that science understanding is three-dimensional: disciplinary core ideas (DCI), cross-cutting concepts (CCC), and science and engineering practices (SEP; NGSS Lead States, 2013). Thus, assessments aligned with the NGSS need to provide insight into students' abilities for each of the dimensions, which is not easily accomplished using traditional assessment methods (National Research Council, 2012). Formative assessments, which provide insight into learning during instruction, are a particular challenge for teachers to enact within a system of assessments. Teachers struggle with interpreting evidence from formative assessments and deciding on the next instructional steps based on that evidence (e.g., Schnieder & Andrade, 2013).

Formative assessment practices can be characterized by three questions (Gotwals, 2018). The first, "where are we going?" addresses the learning objectives. The second, "where are we now?" focuses on using evidence to determine student understanding. The third, "how do we get to the learning target?" involves instructional decisions to close the gap between the answers to the first two questions. Teacher engagement in the formative assessment process involves noticing (Talanquer, Tomanek, & Novodvorsky, 2013). Given the multitude of things to notice, teachers make choices as to what to notice and attend to (van Es, 2011). One way to consider what science teachers notice and do not notice is to consider their noticings in relation to what science educators notice and what literacy educators notice.

Although the SEPs designate literacy as a single practice (i.e., obtaining, evaluating, communicating information), literacy is an integral component of all of the SEPs. For example, constructing explanations requires writing, and developing arguments from evidence requires obtaining information from texts. As such each of the SEPs requires disciplinary literacy (DL) practices, where DL is knowledge of and skill with the literacy practices of a particular discipline, such as science or history (Goldman et al., 2016; Moje, 2015; Shanahan & Shanahan, 2012).

While science educators focus on students' engagement with phenomena, literacy educators focus more on how students are using and producing texts. They consider how students are comprehending the texts, such as making sense of the textbase and developing a situation model (Kintsch, 2013), and how students are making intertextual connections across texts (Goldman, 2004).

The field of literacy education uses think-alouds for the formative assessment of reading comprehension and writing (e.g., Wade, 1990). This study draws on that scholarship to consider the potential of think-alouds as a formative assessment tool in science to provide both evidence about students' proficiency with the three-dimensions of the NGSS and DL practices. Specifically, this work focuses on how two teachers analyzed and planned for future instruction using data from transcripts of think-alouds while their students wrote scientific explanations of cellular respiration. To explore the teachers' analysis and planning, I ask:

1. What do teachers notice in students' writing performances and think-aloud interview transcripts?
2. How do teachers use what they notice to plan for future instruction?

Design and Analysis

To explore my research questions, I used an embedded single-case design with two participating teachers (Yin, 2003). This study was conducted within a larger science education research project. The primary participants of this project are two White female science teachers

from a Midwestern state. Ms. Walker is a sixth-grade teacher in a rural district who has taught for twenty-one years. Mrs. James is a ninth-grade teacher in a suburban district who has taught for seven years and has a Ph.D. in science education. Both teachers enacted the NGSS-aligned project curriculum. Pseudonyms are used throughout this proposal and the research underwent IRB review.

In spring 2018, I conducted think-alouds with three of each teacher's students while the students wrote explanations of cellular respiration answering the question, "how does a cell in a potato plant use glucose for energy to move and function?" The students thought aloud as they completed a graphic organizer and then wrote a paragraph explanation. As resources, they had several relevant texts available for use. These texts included a framework and rubric for writing explanations, a reading, and a completed worksheet from a molecular modeling activity. This task mirrored work that they had done in class previously. After writing their explanations, I interviewed each student for approximately five minutes using questions about scientific explanations and their writing process. The think-alouds were audio-recorded and then transcribed.

In summer 2018, I held a two-day professional development (PD) workshop. As part of the workshop, the teachers analyzed the students' written explanations and the think-aloud interview transcripts. The analysis consisted of three parts: "I notice," "I wonder," and "I wonder what would happen if." The I notice and I wonder components inform the formative assessment question, "where are we now?" and the I wonder what would happen if component answers the formative assessment question, "how do we get to the learning target?" The workshop was video recorded. I also collected artifacts from the workshop including the teachers' notes on the think-aloud transcripts.

To explore my first research question, I coded both the video of the analysis and the teachers' notes on the think-aloud transcripts looking for science-related noticings aligned with NGSS and literacy-related noticings related to how the students used and produced texts. I looked within the codes for patterns. For my second research question, I considered the relationship between the instructional ideas generated by the teachers and the teachers' noticings.

Findings

During the analysis of the think-aloud interviews, the teachers noticed their students' thinking in ways that aligned with what both science and literacy educators would notice. Below I expand on what the teachers noticed and did not notice. I then discuss the instructional plans made by the teachers based on those noticings.

Science-Related Noticings

Science educators are interested in how students are engaging with phenomena along the three-dimensions of the NGSS. Mrs. James and Ms. Walker had noticings along each of the dimensions. However, there were also aspects of the students' proficiency with the dimensions that they did not attend to, particularly with regards to CCCs.

Disciplinary Core Ideas noticings. Mrs. James questioned the extent of her students' understanding. Moving beyond an evaluative frame to an interpretive frame (Davis, 1997), she posed questions she could ask her students to better understand their understanding. Mrs. James suggested asking her student "when does cellular respiration and photosynthesis happen?" to make sense of how a student was understanding the relationship between the two processes.

Mrs. James and Ms. Walker were interested in the origin of their students' understanding of the DCIs. One of Ms. Walker's students stated, "cellular respiration is what…gives us our air to breathe." Despite the inaccuracies in this statement, Ms. Walker noticed that "she remembered

that plants give use air to breathe," and wondered, "is this something she knew before the unit?" Mrs. James showed videos of plants moving in class, but not potato plants. She wondered if this contributed to how her students struggled with explaining cellular respiration in potato plants.

Cross-Cutting Concepts noticings. Both teachers primarily noticed how their students were using the CCC of energy and matter conservation. Mrs. James noticed that one of her students was conserving matter. Specifically, she wrote in her notes, "sense of necessity about conserving matter" in response to the students' statements that "it would take up 12 of your oxygen molecules, and all of your carbon molecules, and then you have 12 hydrogen and six oxygen left." Ms. Walker noticed conflation of matter and energy in her student's idea that "glucose is like the bad energy." The teachers showed more limited noticings related to the CCC of scale, proportion, and quantity. Some of the students were better able to describe the process of cellular respiration across scales than others.

Science and Engineering Practices noticings. The teachers also noticed how their students engaged in the practice of constructing explanations, supported by questions that students answered during the interview including, "what makes a good explanation in science?" Mrs. James saw differences among her students' explanations and interpreted this as indicating different understandings of the nature and purpose of scientific explanations. For example, one of her students wrote an "ELA explanation" with a topic sentence and supporting details.

Mrs. James and Ms. Walker's noticings made them question their own understanding of the practice. They discussed their own perspectives on the question: "what makes a good explanation in science?" Mrs. James also asked, "what is most useful for them to actually know?" This suggests that neither teacher had a clear conception of the answer to the formative assessment question, "where are we going?" specifically related to the desired performance of the SEP.

Literacy-Related Noticings

Mrs. James and Ms. Walker had some, but less elaborated and less analytical literacy-related noticings. They noticed (a) students' abilities to use and interpretations of the resource texts as resources, (b) students' strategies for completing the graphic organizer, and (c) students' strategies for writing the paragraph explanations. For example, Ms. Walker noticed that one of her students used vocabulary words from the resources but questioned if the student understood the words. Mrs. James noticed that one of her students used a resource to revise his explanation. The teachers did not attend to the students' depth of comprehension of the resources and how this related to their ability to use the resources. Some students copied phrases from the resources into their explanations, while others transformed the information indicating a potentially more sophisticated situation model of the resources. The teachers also did not notice the students' abilities to make intertextual connections across resources.

How the Noticings Informed Instructional Decisions

Moving from the second to the third formative assessment question, the teachers considered how to move students to the learning goals. Following the analysis of the think-aloud transcripts, the teachers had limited instructional ideas. Mrs. James suggested having students critique other explanations to help them better understand what makes a good scientific explanation. Ms. Walker wondered what would happen if students were not given the graphic organizer prior to writing their paragraph explanations. This would remove a scaffold so might actually result in a negative effect on the explanations produced.

Another component of the PD workshop was the development of an ideal explanation, in other words, answering the first formative assessment question about where we are going. The

teachers wrote an explanation for charcoal burning. Charcoal burning was a new phenomenon for the teachers but is closely related to the phenomenon in one of the project's units, ethanol burning. The teachers developed a checklist based on their ideal explanations of what they would like students to include. The checklist included, in addition to the science content requirements, names the carbon transforming processes, defines the system, makes connections, uses scientific vocabulary appropriately, and is organized logically to tell a story. The ideal explanation is one that does not simply include the content, but also is well written and draws on multiple texts.

After defining the ideal explanation, the teachers were able to generate more productive instructional ideas that combined what they noticed in the think-aloud interview transcripts with the type of explanations they wanted from their students, along with input from the researchers. The teachers and researchers brainstormed that it would be helpful to have a reading strategy or tool for students to use while completing the readings in the curriculum. This would support students in interpreting the readings and using the readings as resources. This came out of the noticings that not all the students were able to use the available texts to write their explanations.

The teachers also considered revising the end of the unit to support students in writing an integrated explanation telling the whole story of how a plant moves, grows, and functions. This came out of the noticings that students struggled to situate the process of cellular respiration with respect to other processes in the plant. These and other ideas drew on their noticings and the ideal explanation activity to address the gap between where we are and where we are going.

Contribution to the Teaching and Learning of Science

This work contributes to a model of PD that engages teachers in the challenging practices of analyzing formative assessment data and making instructional decisions based on that data. By having a researcher conduct the steps of developing and administering the formative assessment, the teachers were able to focus on the analysis and instructional implications. The structure of the analysis built on noticings and wonderings was accessible and open allowing teachers to notice a variety of aspects of their students' understanding that related to both science and literacy. Given the teachers' expertise, they were more apt to make science-related noticings, but able with support and prompting to also make literacy-related noticings.

Moreover, this work suggests the importance of defining the learning goals, as the teachers were unable to generate potentially productive instructional decisions prior to developing an ideal explanation. It was only after writing the ideal explanation that teachers drew on their science- and literacy-related noticings, with the support of the researchers, to figure out instructional steps that may bring their students closer to the ideal explanation.

Additionally, this work is illustrative of how teachers can come to understand the integral nature of disciplinary literacy practices and the SEPs. Through the analysis of the think-aloud transcripts, the teachers came to see the central role of texts in the work of science. To construct explanations, students are involved in obtaining information from texts and developing their own texts. By noticing the centrality of texts in the SEPs, teachers will then be better able to support their students with this element of the practices.

Lastly, this study suggests that the type of think-alouds used in this study may be a potentially fruitful formative assessment tool to support teachers in thinking about their students' science and literacy practices. Even it is impractical for teachers to do entire think-alouds, they can ask students to share their thinking while they are engaging in the SEPs and ask some meta-level questions, such as what makes a good explanation and why they are writing an explanation.

Contribution to the Interests of NARST Members

This paper will draw together NARST members from different strands interested in assessment, professional development, and literacy in science to consider how PD can support the formative assessment practices of teachers. Moreover, this work connects to the 2019 NARST theme as this work crosses traditional subject area bounds to learn from those outside of science education research about alternative forms of assessment and to consider the literacy elements of the SEPs.

References

Davis, B. (1997). Listening for differences: An evolving conception of mathematics teaching. *Journal for research in mathematics education*, 355-376.

Goldman, S. R. (2004). Cognitive aspects of constructing meaning through and across multiple texts. *Uses of intertextuality in classroom and educational research*, *317352*.

Goldman, S. R., Britt, M. A., Brown, W., Cribb, G., George, M., Greenleaf, C., ... & Project READI. (2016). Disciplinary literacies and learning to read for understanding: A conceptual framework for disciplinary literacy. *Educational Psychologist*, *51*(2), 219-246.

Gotwals, A. W. (2018). Where are we now? Learning progressions and formative assessment. *Applied Measurement in Education*, *31*(2), 157-164.

Kintsch, W. (2013). Revisiting the Construction-Integration Model of text comprehension and its implications for instruction. In D. E. Alvermanm, N. J. Unrau, & R. B. Ruddell (Eds.), *Theoretical models and processes of reading* (6th ed.) (pp. 807-839). International Reading Association: Newark.

Moje, E. B. (2015). Doing and teaching disciplinary literacy with adolescent learners: A social and cultural enterprise. *Harvard Educational Review, 85*(2), 254-278,301.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

NGSS Lead States. (2013). *Next generation science standards: For states, by state*s. Washington, DC: The National Academies Press.

Schneider, M. C., & Andrade, H. (2013). Teachers' and administrators' use of evidence of student learning to take action: Conclusions drawn from a special issue on formative assessment. *Applied Measurement in Education*, *26*(3), 159-162.

Shanahan, T., & Shanahan, C. (2012). What is disciplinary literacy and why does it matter? *Topics in Language Disorders, 32*(1), 7-18.

Talanquer, V., Tomanek, D., & Novodvorsky, I. (2013). Assessing students' understanding of inquiry: What do prospective science teachers notice?. *Journal of Research in Science Teaching*, *50*(2), 189-208.

van Es, E. A. (2011). A framework for learning to notice student thinking. In *Mathematics teacher noticing* (pp. 164-181). Routledge.

Wade, S. E. (1990). Using think alouds to assess comprehension. *The Reading Teacher*, *43*(7), 442-451.

Yin, R. K. (2003). *Case study research: Design and methods* (Vol. 5.). Thousand Oaks, Calif: Sage Publications.