THE CO-CONSTRUCTION OF INQUIRY IN THE SCIENCE CLASSROOM BY CURRICULUM DESIGNERS AND TEACHERS (KATHRYN DRAGO)

Introduction

Within science education literature, inquiry takes on at least 18 distinct meanings (Duschl & Grandy, 2008). This multiplicity of uses has led science education researchers attempting to advance the field to call for a “greater precision and consistency” of the definition of inquiry (Hofstein & Lunetta, 2004) or to completely abandon the word for a more rigorous term (Michaels, Shouse, & Schweingruber, 2007). For teachers, the variation in the definition of inquiry presents an enactment problem as national science education standards (American Association for the Advancement of Science, 1993; National Research Council, 1996) require teaching scientific inquiry in all grades. While the confusion surrounding the meaning of inquiry creates challenges for education researchers and teachers alike, it also provides a space in which, through partnership, these groups can collaborate to refine thinking about what inquiry is and how to best support inquiry-based instruction.

In this study, I analyze a conversation between science education researchers and inservice middle-school science teachers as they discuss a recent enactment of pilot curriculum materials designed by the researchers. I focused this analysis with the question: What insights can a collaborating group of science curriculum designers and inservice science teachers bring to inquiry in the science classroom? Discourse analysis (Gee, 2005) of this conversation revealed the strengths and weakness of the curriculum in terms of presenting and supporting inquiry in the classroom, and it resulted in substantial changes in the next version of the materials. Here I discuss the affordances and constraints that this language-based methodology provided as I constructed a refined conception of inquiry in the science classroom based on the discourse between the curriculum designer-researchers and teachers.

Context: Debriefing as a Component of a Design-Based Curriculum Development Project

The discourse analyzed in this paper is one component of a large-scale design experiment developing and assessing the Investigating and Questioning the World through Science and Technology (IQWST) curriculum (Krajcik, McNeill, & Reiser, 2008). IQWST is a 6th through 8th grade curriculum which contains 12 8-week units: 1 unit for biology, earth science, chemistry, and physics for each grade. The materials align with national middle school standards for science content and practices and help students to build a coherent understanding of science across grades and science content areas. Curriculum designer-researchers provide piloting teachers with highly developed, specified, and educative lesson plans (Cohen & Ball, 1999), student worksheets, student reading materials aligned with in-class activities, and all unusual science equipment and materials called for by the unit.

By design, IQWST is an inquiry-based curriculum. Because inquiry has so many meanings in science education, it is useful to further define how this term relates to the
IQWST curriculum. First, the curriculum designers espouse the commonly accepted definition of inquiry stated in the National Standards for Science Education:

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (National Research Council, 1996).

Second, the IQWST designers leverage this definition of inquiry as both educational means and ends (Abd-El-Khalick et al., 2004). To further explicate this distinction, I will use the 8th grade IQWST chemistry unit (Food/Energy Unit), which is the topic of the discourse presented in this paper, as an exemplar. When using inquiry as means, Food/Energy Unit designers exploit inquiry as a pedagogical approach which helps students achieve scientific content learning goals: building understanding of the molecular nature of food, chemical reactions in living things (i.e. photosynthesis and cellular respiration), and the flow of matter and energy through organisms. As an example, in one activity students use probes to measure the concentration of carbon dioxide in their breath before and after exercising. Analyzing these data allows students to make the claim that they exhale more carbon dioxide after exercise and link energy use to carbon dioxide production by the cells of the body. Instead, when the curriculum designers utilize inquiry as ends, students’ learning focuses on the nature of science and the skills of inquiry. In the Food/Energy Unit, students refine their understanding of designing investigations and data gathering, organization, and analysis. Using the same example above, students investigate what makes the data they collected sound and how to generate new scientific questions using the data they gathered. Therefore, both inquiry as means and ends can be served simultaneously.

The design process for the IQWST curriculum involves piloting early versions of each unit on a small-scale and revising based on a variety of data such as classroom observations, teacher and student interviews, teacher feedback, student work, and student pre/posttests. The discourse presented in this paper occurred during a three-hour debriefing session held between three curriculum designer-researchers (one of which is the author) and three teachers after they had piloted the Food/Energy Unit. Two teachers (Kyle and Sam, all names are pseudonyms) taught at a private school in a Midwestern college town, while the third (Aaron) taught at a public school in a large Midwestern urban center. All teachers had experience teaching inquiry-based science curriculum and had a long-term partnership with the curriculum design/research group. The debriefing session was formatted such that the teachers started by expressing their overall feelings about the units and then discussed each lesson in detail. Though the teachers said they had many positive comments, the curriculum designers-researchers asked them to focus only on the challenges they confronted with the curriculum due to the time constraints of the meeting. As the teachers discussed their enactment, the curriculum designers asked clarifying questions and presented possible solutions for discussion.

Analytic Methods
The discussion between the teachers and curriculum designers/researchers was informal and far-reaching. Because I wanted to focus specifically on inquiry, I started by performing a content analysis on a transcript of the meeting in which I highlighted discourse relating to inquiry for further analysis. I categorized these selections as relating to inquiry as means and ends. From this preliminary analysis, I found that inquiry as means far outreached inquiry as ends in terms of the amount of discourse. At this point, although the transcript was redacted, I still had a wealth of data relating to inquiry. For the purposes of the revisions of the curriculum, I needed to understand how I ought to change the materials to better support inquiry. Therefore, I performed a thematic analysis on the inquiry-specific discourse. Categories of themes I produced from this analysis include need to better support inquiry as means through 1) giving students the cognitive and physical tools necessary to make inquiry successful and 2) structuring activities which allow students to make meaning from their observations. As inquiry as ends was not well covered in the discourse, I did not perform a thematic analysis of this category. The above analysis is not included in this paper.

While I was rereading the transcript of the discourse, I found sections of the conversation in which there was some tension between the speakers. In these sections, the teachers challenged the curriculum designers or each other to view inquiry according to different perspectives. Therefore, I saw these sections to be the most valuable for building a new understanding of inquiry. I selected these samples of the conversation, which contained this generative tension, to analyze using discourse analysis. I retranscribed the selected discourse to capture some linguistic detail. I denote pauses (...), emphasis (*), elongation of word segments (:), change in speed ([ac] accelerated or [dc] decelerated), and change in intonation ([hi] high and [lo] low). I analyzed these selected passages especially for the significance the speakers give to inquiry and how what they say is in Conversation with the idea of inquiry as conceived by the curriculum designers and the larger science curriculum reform movement.

**Discourse Analysis: Findings and Implications**

Discourse analysis revealed that the curriculum designer-researchers and teachers held the same basic definition of inquiry, and therefore could productively discuss how the curriculum could better support it. Additionally, both parties shared the idea that inquiry can be used as both means and ends. However, while inquiry as means was taken as matter of fact, inquiry as ends was a less universally leveraged in the classroom. Although the teachers supported the principle of inquiry as means, they asked the curriculum designers to integrate more support for helping students to understand the science content that underlies inquiry activities. The activities themselves were not enough to drive student sense making. In contrast, when talking about inquiry as ends the teachers did not ask for better support, but instead reminded the curriculum designers and each other that this was a valuable undertaking. Thus, through discourse, it seemed like the curriculum needed to better situate inquiry as means within a context of science content learning and needed to elevate inquiry as ends. Based on this discourse, I made substantive changes to both the teacher and student materials to better support both forms of inquiry in the classroom. In the sections below, I discuss how discourse analysis led
me to these claims, and the affordances and constraints I encountered with this language-based methodology.

**Discourse Analysis: Finding the Right Balance to Support Inquiry as Means**

As conceived by the curriculum designers, during enactment students carry out in-class investigations which showcase scientific phenomena. Teachers help their students make sense of their observations, and student readings aligned with the in-class activities, assigned as homework, reinforce learning. However, it seemed that during enactment of the curriculum, this scenario was not playing out as planned. In the following statement, Kyle summarized the challenge she and her students faced.

I think the kids were lost in the activities. And then they had to do the student reader and figure out what’s going on. Rather than... And you want them to explore the phenomena, right? But the, but, but...too many of the kids, not just the regulars, too many of the kids, um...didn’t, didn’t make sense of stuff until they read the student reader. So the activity itself wasn’t enough.

Through her words, Kyle built meaning about inquiry and the way in which she saw it as a useful practice in her class. First, by emphasizing the word “explore” through elongation, she showed that she valued this activity as one of the many facets of inquiry. The curriculum designers also agree that guided exploration of scientific phenomena (as opposed to pure discovery learning) should be the primary means for learning science. Kyle knew that her ideas about exploration were aligned with those of the curriculum designers (and the science curriculum reform movement as a whole), and she signaled this by asking the rhetorical question “right?”

But, while she affirmed the importance of exploration, Kyle also made several linguistic moves which showed it needed to be better situated in the curriculum to provide more powerful learning experiences for her students. First, she stressed the word “lost” to draw attention to the importance she places on this problem with the curriculum. Then, she further expounded on the nature of her students being lost. She commented this was a too common occurrence which affected students across ability levels (“not just the regulars”). Thus, she underlined the severity of this challenge during enactment.

Finally, Kyle’s discourse hints at the reason why inquiry as a means was at times not successful in the classroom. When she said that her students “had to do the student reader and figure out what’s going on,” her choice of the words “had to” and “figure out” suggested that she negatively viewed this task. “Had to” suggested that there should have been another activity fulfilling this sense-making role, and “figure out” connoted lack of guidance and possible frustration for the students. This word choice contrasts with something she might have said if she had positively viewed this task (i.e. the student reader allowed the students to solidify a deep understanding of the activities). Further supporting this idea, she began the next sentence stressing “rather than.” Although she did not complete this utterance, she was clearly juxtaposing using the student readers as a sense-making tool (which happened in the enactment) with a structure for the curriculum that would better support learning. Most explicitly, she ended her comments with the “activity itself wasn’t enough.” Therefore, while exploration is important, simply participating in an activity does not provide enough support to foster learning.
When one of the curriculum designers asked Kyle if she thought that the problem which caused her students to be lost was a lack of support in the teacher materials she answered

[lo] Well..that, and maybe the activity itself. You know, you have to find the balance where you give the kids *enough* so the activity’s meaningful, but not [hi] too much that they don’t learn from the activity. You have to find that balance...And what *I* think was that balance *wasn’t* found.. in the..that there was too:: much of kids [dc] not quite knowing what they’re doing, and then not getting.. *enough from it* because of that.

This statement is clarifying follow up to Kyle’s last comment. Here, she still valued the inquiry activities as pedagogical tools. However, she saw the need to support them appropriately to achieve the best learning outcomes. Starting her comment with a low tone showed that she was considering the possibility that the teacher materials were to blame for her students being lost, but she more strongly believed that another aspect of the curriculum was at fault. She continued by setting up the perfect scenario for an in-class activity stressing “enough” and emphasizing “not too much” through intonation. Thus, she created the idea that the perfect “balance” leads to the optimal enactment of inquiry as means.

Then, she took ownership of the balance idea by emphasizing “I” and contrasted it with the curriculum designer-researcher’s idea that the teacher materials are not supportive of student learning. She concluded by highlighting her reasoning that students were lost because the balance for the in-class activity “wasn’t found” and students did not get “enough from it.”

Through these statements, Kyle was able to express the nuances of inquiry as means which allow students to learn scientific concepts through it. Both she and the curriculum designers-researchers valued inquiry in the classroom, and both understood that inquiry must be well supported for students to draw meaning from their activities. However, during the curriculum development process, the emphasis is oftentimes placed on the activity itself with less time dedicated to developing the structure necessary to support meaning-making. The result is that the curriculum unintentionally embodies a vision of inquiry as means in which engaging in scientific enterprise is sufficient for student learning. In her two comments, Kyle reported that as developed, the curriculum did an inadequate job of supporting student learning. She challenged the curriculum designers to reevaluate the concept of inquiry as means and to revise the curriculum to align with this reformulated vision.

**Discourse Analysis: Differential Emphasis on Inquiry as Means and Ends**

Although discourse about inquiry as ends was rare, it is useful to compare the nature of the discussion about inquiry as means and ends. Conversation about a lesson in which groups of students exercise and use instruments to collect data about their bodies sparked discourse about inquiry as ends. All of the teachers agreed that there were technical difficulties with the instruments in this experiment. The pedometers did not always work, and a few of the probes were either too sensitive or “sporadic.” This left
some students without data or with inconsistent results that confounded their attempts at formulating claims from evidence. Suggestions ranged from letting the students have more time to “practice with the probes,” to investigating how the probes work best, to replacing some of the probes with more reliable, low-technology means of measurement. While most of the conversation focused on how to avoid these challenges in the future, Aaron’s comment provided an interesting contrast. When asked by the curriculum designers-researchers if he experienced any challenges with the equipment, he responded

Yeah, there were challenges with the technology, but just...yeah, I think I used it as the time to talk about the challenges with the technologies, and to generate some discussions as...to why the numbers probably should have came out one way but.. it didn’t.

Here, Aaron agrees with the other teachers that the technology did present some challenges, yet he uses linguistic cues to distance himself from seeing them as negative. First, he chooses the phase “there were challenges.” This construction removes Aaron from the challenges as opposed to owning or identifying with them (i.e. we had a lot of challenges). Second, Aaron elongates the pronunciation of “were” which sets up the sentence to juxtapose the challenges with a more positive concept. In support of this, he starts his second phrase with “but” and continues to say that the challenges provided generative discussions about discrepant data (“why the numbers probably should have came out one way but it didn’t”). Thus, Aaron saw the value in certain difficulties in science class and used them to positively drive learning about inquiry as ends.

It is interesting to note that while the discussion about inquiry as means focused on how the curriculum designers could better support learning science content through inquiry, this discussion about inquiry as ends simply signified that it can be a valuable part of the curriculum. Therefore, it seems that although teachers, curriculum designers-researcher, and the science education reform movement valued inquiry as ends, it was poorly translated into the curriculum. During the curriculum development process, inquiry as means is central, whereas inquiry as ends is often an afterthought. The lack of discourse about inquiry as ends in the debriefing session coupled with only one out of three teachers leveraging inquiry as ends during this activity, challenges the curriculum designer-researchers to elevate and support inquiry as ends in the revised materials.

Discourse Analysis: Affordances and Constraints

In this work, I found discourse analysis to be a powerful tool which allowed me to investigate the building of the significance of inquiry between teachers and curriculum designer-researchers. As one of the curriculum designers, I often find myself making meaning of teachers’ discourse through my own perspective. For example, when I left the debriefing meeting which is the source of this discourse, I had a list of suggestions for how to improve the curriculum. This list served me well as a curriculum designer since my function was to revise problematic aspects of the curriculum. Yet, looking at these notes now, I find them disjointed and shallow with regard to inquiry. With them, I am only able to address the specific challenges which the teachers mentioned. My list does not allow me to identify other problematic areas in the materials based on a larger concept, nor does it allow me to apply this larger concept to new curricula.
This rather close discourse analysis pushed me to discover “better, deeper, more humane interpretations” (Gee, 2005). Instead of basing my claims on immediate perceptions during the meeting, discourse analysis led me to reflect on and consider the data from multiple perspectives. It allowed me to understand the process of building the meaning of inquiry and even situate it in the larger Conversation of inquiry in the curriculum and inquiry in the science reform movement. From this analysis, I conclude that inquiry as means must be supported by balanced meaning-making opportunities which provide optimal learning for students. Inquiry as ends, although valued in theory, must also be supported in the materials. Applying these finding will improve the quality of current revisions and future curriculum development.

While discourse analysis offered these affordances, it is not appropriate for every circumstance. This close analysis is useful for making meaning from small units of discourse. Therefore, I would not apply this same methodology to the entire three-hour transcript of the debriefing meeting. To perform this type of analysis, preliminary analyses (for example, my content and thematic analyses) and strong selection criteria are necessary to make data selection valid. Additionally, I find discourse analysis most useful when employed as one of several methodologies analyzing the same data. For instance, while I performed discourse analysis on the conversation from the debriefing meeting, I also had the teacher complete a detailed questionnaire about the curriculum. The discourse analysis provided me with the meaning for the revisions, while the survey provided me with the content. With only the discourse analysis, I would be less affective in the revision process. In summary, in science teacher education, discourse analysis, especially when leveraged with other methodologies, is useful for building and defining the significance of inquiry between diverse interacting groups. The meaning that is produced from this analysis can then be applied to various pursuits including improving teacher education, curriculum design, and student learning outcomes.


