Whole-Group Question-Asking in Two Classrooms During a Complex Causal Science Curricular Intervention

Maleka Donaldson Gramling and Tina Grotzer
Harvard University

Purpose

Human kind faces myriad environmental issues, such as climate change and pollution, which will require sophisticated thinking to address effectively. It is critical to help the next generation of students to become aware of both the complex workings of these phenomena, as well as the profound impact of human behaviors on the global ecosystem. Many of the mechanisms by which ecosystems phenomena work are diffuse and difficult to attend to, collectively influenced by distributed agents around the world who are unaware of the impact of their individual actions. As such, helping students to better reason and attend to complex causality in their world presents a challenge for science educators, but is one well worth the investment. In order for the next generation to be able to navigate the global issues of the future, students must become critical thinkers who are able to both respond to and generate questions that help them to deeply understand complicated scientific problems. Teachers can play a central role in developing these reasoning abilities in students. This can be promoted both by improving their critical thinking skills and also helping them to "think like scientists", thereby enhancing student observation and question-asking abilities in ways to help to more aptly address global environmental concerns.

In this paper, the authors present an opportunistic analysis borne out of a large, multi-year research study. The larger study is focused on understanding student complex causal reasoning regarding ecosystems and other natural phenomena, and developing evidence-based curriculum to hone students' causal thinking skills. While the broader research study centers on the assessment of student thinking and reasoning, the aim of the present mixed-methods study is to articulate variations in how teachers execute the causal learning curriculum, primarily indicated through patterns of question asking and response during whole-class discussions. By investigating the ways educators interpret the curriculum and, subsequently, guide classroom discussions, we hope to provide additional guidance to teachers that can help improve student complex causal reasoning.

Theoretical framework: Classroom Discussion and Question-Asking in Science Education

Educators influence student approaches to science, particularly through the ways teachers engage with and respond to student ideas (Wertsch, 1998). These teacher-student interactions are both verbal and social, and the ways they impact science classroom learning are substantial (Reinsvold & Cochran, 2012). Furthermore, discussions in the science classroom are a critical means to help students understand challenging science content, providing opportunities to practice thinking and communication skills that can enhance learners' ability to engage in science learning and problem solving (Herrenkohl & Guerra, 1998; Harris, Phillips & Penuel, 2012). This is especially relevant to the learning and teaching of complex causal mechanisms in ecosystems science, which prior work has shown are very challenging for students to understand and attend to (Rickinson, Lundholm, & Hopwood, 2010; Grotzer, Kamarainen, Tutwiler, Metcalf, & Dede, 2013). Furthermore, leading discussions in science education "requires that teachers have a solid grasp of the science ideas under study as well as some anticipatory sense about how to move students forward in their thinking" (Harris, Phillips & Penuel, 2012, p. 770), thereby making the task for the educator both challenging and effortful (Alozie, Moje, & Krajcik, 2010).

Decades of prior work indicate that question-asking is an important way to help facilitate the development of deep student understanding, particularly high-quality (Lustick, 2010) and open-ended questions (Lee & Kinzie, 2012). In their review of the current literature on questioning in the context of literacy instruction, Lee and Kinzie (2012) note that teachers' effective use of questions in classroom discussions can help to develop the ability to reason, promote reflection, and develop student use of specialized vocabulary and willingness to share ideas. At present, work specifically focused on question-asking in the science classroom is fairly limited (Lustick, 2010). Going forward, this should be an area of focus because it can be quite challenging to promote robust inquiry in science, both due to teachers' own conceptions of science (Saad & BouJaoude, 2012) as well as habits of questioning techniques (Almeida & DeSouza, 2010). Also, the social aspect of classroom dynamics is too often neglected in research on question-asking, but is a notable element of the student's experience (Eshach, Dor-Ziderman & Yefroimsky, 2014)

Building on this literature, in the current study we ask the question: *In a comparison of two classrooms engaged in a curricular intervention, what differences and similarities are there in classroom question-asking behaviors during whole-group discussions and what are the implications for the development of inherently complex causal reasoning skills?*

Methods

Sample

Students and teachers were from two science classrooms at schools in the Northeast U.S. These two classrooms are a subsample of a group of seven participating in a larger study on students' reasoning across large spatial scales. One science teacher taught a classroom of 24 sixth-graders at Impact Charter School[*], located in a small, urban city. Over 90% of students in the school were Latino and greater than 50% were eligible for free/reduced price lunch (FRPL). The science teacher in the second class taught 40 sixth-graders at Heyville Middle[*], a suburban public school with ~10% of students from underrepresented, racial minority groups and <10% FRPL eligible.

Procedure

Each participating science teacher taught their students one module from the Causal Learning in the Classroom (CLiC) curriculum, a research-based curricular intervention with the aim of improving students' attention to and understanding of causal mechanisms in their world. In Spring 2014, teachers taught the module in five, hour-long blocks over the course of approximately one to two weeks. CLiC Module One is comprised of four lessons that include a variety of activities designed to expand students' causal reasoning. For example, students are asked to define the terms "cause" and "effect", to generate real-world examples from their own lives, to compare and contrast examples of emergent outcomes in recent natural disasters and in a case study, and to generate suggestions for how to help themselves and others to more frequently attend to their role in emergent outcomes. All classroom discussions and activities were designed with the aim of drawing student attention to spatially separated causes and effects, and making

[*] a pseudonym

connections between the science concepts and events and observations from national news and/or their own lives.

Data Source

In this paper, we present the details of an opportunistic analysis of data collected during the CLiC Study, which focuses broadly on understanding the impact of the CLiC intervention on students' complex causal reasoning. In the two participating classrooms, all class periods in which CLiC was taught were videotaped and audio recorded by the researchers. The digital video recorder was set up at the back of the classroom and, typically, small audio recorders were placed around the room to help capture the teacher and student voices throughout the course of the lesson.

Coding and Analysis

The classroom content relevant to the guiding research question was question-asking during whole-class discussion, so all portions of the video/audio during small group or individual work time or one-on-one, teacher-student interactions were excluded from this analysis. Additionally any lecture was omitted, as well as general statements made by teachers and students that were not connected to questions and/or responses to questions (e.g., classroom management). Relevant portions of the classroom discussions were transcribed and a variety of quantitative and qualitative information was collected in relation to each question asked and the responses following.

Quantitative coding approach. A simple codebook was developed which included precise definitions of various attributes of each discussion. During transcription, for each turn in the discussion, research assistants recorded:

- Type of discussion comment (question, response, statement or other)
- Origin of the comment (teacher or student(s))
- Timestamp indicating when the comment started
- Wording of the comment

These data were used to compute counts and proportions of questions and responses by classroom and by comment origin. The result was a quantitative based description of each question-asking environment which can be used to compare and contrast the two classrooms.

Qualitative approach. Emergent coding was utilized in order to identify broader themes and patterns in question-asking behaviors from the classroom video and corresponding transcripts (Charmaz, 2006). For purposes of reliability, the lead author and another research assistant separately watched each video, one class period at a time. With the research question in mind, the researchers independently took notes on patterns observed, as well as other observations that seemed particularly striking, puzzling, or otherwise noteworthy. Afterwards, the two researchers met and discussed their notes and recounted specific instances, jointly compiling a memo that represented common, agreed-upon patterns and observations. This process was then repeated one class period at a time. Once emergent coding memos were completed for all five Impact Charter School videos, an overarching memo was written that compiled memos and evidence from across the class periods. Then the entire process was repeated for the five Heyville Middle School class session videos.

Findings

The following overarching trends were observed during the emergent coding and quantitative analysis of the question-asking and response behaviors.

Impact Charter – Teacher Centered Discussion, Quiet Students

In the Impact classroom, the whole-group discussions during the CLiC lessons tended to be teacher-centered, meaning that students only interacted directly with the teacher, and not with each other. The driver of the discussion was the teacher, reflected by the fact that the teacher spoke almost twice as much of the time (Students: 11% of class time; Teacher: 22%). Throughout the lessons, the teacher controlled the flow of the conversation, and students often asked permission from the teacher to speak or ask a question. After collecting several student responses, the teacher often provided a summary statement of the conceptually “correct” answer before moving on. Also, there appeared to be different levels of affirmations that the teacher gave to each student response as an acknowledgement of an acceptable response and/or an assessment of its quality (e.g., “Good!”; “Yeah, that sounds good, I like that.”)

Heyville – Teacher as Discussion Facilitator, Talkative Students

The Heyville teacher seemed to promote the collective development and advancement of ideas and inquiry. During whole-group discussions, there was balance in the amount of time the teacher had the floor versus when the students were speaking (Students: 17% of class time, Teacher: 19%). The teacher often invited students to be in conversation with all members of the classroom, teachers and other students included (e.g., “Ok, does someone wanna add to that?"), and tended not to assess or judge the quality of student responses, instead allowing students talk without teacher interruption.

Some Cross-Classroom Comparisons

Although students in both classrooms asked similarly low number of questions (1% of class time and ~20 instances in both cases), the Impact teacher asked 68% more questions per class period than the Heyville teacher did (Impact: 52; Heyville: 31). Overall, Heyville students collectively spent 52.4% more time giving responses during whole-group discussion than their Impact counterparts.

Discussion

The findings reveal that, although the teachers used the same curriculum during the same length of time, there were substantial differences in the ways they led the classroom discussion. At Impact Charter, the teacher was the anchor for the discussion, and used questions to guide students toward particular understandings of action at a distance, and scaffold the ability of quiet students to compose verbal responses by probing for additional information. By contrast, the Heyville teacher allowed students to drive the direction of the discussion, allowing eager student respondents to speak freely, while peppering the discussion with simple questions as needed to urge explanation.

Differences such as those outlined above likely impact the learning outcomes related to the larger study. Despite attempts to develop lesson directions that are clear, direct, and pedagogically aimed at the heart of the curriculum objectives, there are some interactional components, like the question-asking styles described above, that may impact student learning. While it is important to allow for teachers to be flexible in their use of the materials in order to adapt to their unique classroom needs, particular types of elaboration might be a good way to help improve the function of certain activities in the lesson. Additional analyses of this data set could further outline the frequency and function of particular question-asking behaviors observed in the classrooms, unpack the execution of particular strategies the teachers used, and more directly explore the connections between the classroom practices and the complex causal concepts that were being taught. Question-asking styles could comprise one of the fidelity of implementation measures related to the learning outcomes of the broader study. And future studies could investigate the impact of more versus less elaborated instructions in curriculum to help clarify how and to what degree the ways teachers execute lessons promotes complex scientific reasoning.

This work has implications for curriculum design, particularly when the aim is deep processing of complicated educational material, as in the case of teaching complex causal reasoning skills. By improving curricular interventions such as CLiC, we hope to help science teachers to better support the development of learners' critical thinking and causal reasoning skills in the ecosystems learning, as well as in real-world, environmental problem-solving they face beyond the classroom.

Acknowledgements

The authors would like to thank Amber Boyd, Kasia Derbiszewska, Amani Messenger-Hayes, Daniel Oh, Rosemarie Sese, Eva Shultis and S. Lynneth Solis for their contributions to this project.

This work is supported by National Science Foundation, Grant No. NSF#0845632 to Tina Grotzer. All opinions, findings, conclusions or recommendations expressed here are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

Almeida, P., & de Souza, F. (2010). Questioning Profiles in Secondary Science Classrooms. *International Journal Of Learning And Change, 4*(3), 237-251.

Alozie, N. M., Moje, E. B., & Krajcik, J. S. (2010). An analysis of the supports and constraints for scientific discussion in high school project-based science. *Science Education, 94*(3), 395–427.

Eshach, H., Dor-Ziderman, Y., & Yefroimsky, Y. (2014). Question Asking in the Science Classroom: Teacher Attitudes and Practices. *Journal Of Science Education & Technology, 23*(1), 67-81.

Grotzer, T. A., Kamarainen, A. M., Tutwiler, M. S., Metcalf, S., & Dede, C. (2013). Learning to Reason About Ecosystems Dynamics Over Time: The Challenges of an Event-Based Causal Focus. *BioScience*, 63(4), 288-296.

Harris, C. J., Phillips, R. S., & Penuel, W. R. (2012). Examining Teachers' Instructional Moves Aimed at Developing Students' Ideas and Questions in Learner-Centered Science Classrooms. *Journal Of Science Teacher Education, 23*(7), 769-788.

Herrenkohl, L. R., & Guerra, M. R. (1998). Participant structures, scientific discourse, and student engagement in fourth grade. *Cognition and Instruction, 16*(4), 431–473.

Lee, Y., & Kinzie, M. B. (2012). Teacher Question and Student Response with Regard to Cognition and Language Use. *Instructional Science: An International Journal Of The Learning Sciences, 40*(6), 857-874.

Lustick, D. (2010). The Priority of the Question: Focus Questions for Sustained Reasoning in Science. *Journal Of Science Teacher Education, 21*(5), 495-511.

Reinsvold, L. A., & Cochran, K. F. (2012). Power Dynamics and Questioning in Elementary Science Classrooms. *Journal Of Science Teacher Education, 23*(7), 745-768.

Rickinson, M., Lundholm, C., & Hopwood, N. (2010). *Enhancing environmental learning. In Environmental Learning: Insights from research into the student experience* (pp. 97-107). New York, NY: Springer.

Saad, R., & BouJaoude, S. (2012). The Relationship between Teachers' Knowledge and Beliefs about Science and Inquiry and Their Classroom Practices. *EURASIA Journal Of Mathematics, Science & Technology Education, 8*(2), 113-128.

Wertsch, J. V. (1998). Mind as action. New York: Oxford University Press.