Multimodal Texts and Tasks in Elementary Project-based Science

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Abstract: This paper describes a study conducted in the context of a larger design-based research project investigating the integration of science, English language arts, and mathematics in elementary grades project-based learning. This study focuses on one third-grade unit in which students read and created multiple multimodal texts, in print and digital forms. Focusing on the design and enactment of two focal texts and associated tasks, we ask: (1) How did the design and enactment of the texts and tasks support third-graders' science and literacy learning? (2) How might modifications to the design of the texts and tasks better support student learning? Findings indicate ways in which the design of the texts and tasks, and the teacher's enactment, synergistically supported students' science and literacy learning, but also point to missed opportunities in the design of the curriculum and its enactment, for further supporting the learning of all students.

Keywords: Multimodal literacy, science learning, designed learning environments, project-based learning

Introduction and purpose

Influenced by the growing range of digital technologies for communication, literacy scholars (e.g., Jewitt, 2008) have called for instruction that builds toward multimodal literacy; that is, the ability to learn from text in which words are used in combination with audio, visual, and spatial modes (Mills, 2010). Dalton (2012) argued that the Common Core State Standards (CCSS, 2010) "assume that being literate means being *digitally* literate" (p. 333) and that to be prepared for the 21st century demands of school, life, and work, students must be able to analyze and create both print and non-print texts using traditional and new forms of media (p. 333). However, some studies have found that, even when multimedia texts were recommended, elementary-grades teachers did not use these resources (e.g., Brenner, Hiebert, & Tompkins, 2009). Hence, studies that investigate the processes and outcomes of incorporating multimodal and digital texts into elementary-grades instruction are needed.

The present study was conducted in the context of a multi-year design-based research project that integrates science, English language arts (ELA), and mathematics in elementary grades project-based learning (PBL), called Multiple Literacies in Project-based Learning (MLs). PBL hypothetically provides opportunities for students to interpret and produce multimodal text as they explore real-world problems. Project-based science instruction, in particular, may provide unique opportunities to explore how students and their teachers use, create, and learn with multimodal text because, as Lemke (2004) argued, scientific literacy is inherently multimodal and scientific disciplines are "leading the way" in the use of video, graphical displays, and simulations to pursue research questions.

While project-based science may provide opportunities for students to interpret and produce multiple modes, we know very little about how young students and their teachers take up these opportunities in diverse classroom settings. Prain and Waldrip (2006) found that, while teachers incorporated multiple modes into science instruction, they did not systematically support students to translate across modes, and students required varying levels of support to interpret modes. This raises questions about how young students and their teachers can be supported to interpret and produce multiple modes of representation as they engage with disciplinary texts and with one another. The current study is consistent with the ICLS 2018 focus on *unpacking the complexity of the learning and teaching process, exploring learning in real-world settings, and understanding how learning may be facilitated with and without technology*. Reflecting this call, design-based studies are needed to understand how multimodal texts and tasks can be designed and used to support students' knowledge building and literacy development.

This study was conducted in the context of one third-grade project-based unit, framed by the driving question: *Why do we see so many squirrels but we cannot find any stegosauruses?* The unit was enacted in a diverse third-grade classroom, in which the class studied organisms' traits and interdependent relationships in ecosystems. The unit featured multimodal texts and tasks designed to advance students' literacy and science learning. To investigate the design and enactment of the texts and tasks, we ask: (1) How did the design and enactment of multimodal texts and tasks support third-graders' science and literacy learning in the context of PBL? (2) How might modifications to the design of the texts and tasks better support third-graders' science and literacy learning?

Theoretical perspectives

The RAND Reading Study Group (2002) proposed that reading comprehension can be explained by considering the reader, the text, the activity in which the reader and text are involved, and the sociocultural context in which the activity takes place. This study focuses on students' interpretation and knowledge building in the context of reading, interpreting, and creating multimodal texts. This work is also informed by sociocultural theories of learning, which reject the view that knowledge is located within the individual and, instead, embrace the view that learning and understanding are inherently social, occurring through interaction, negotiation, and collaboration (Wertsch, 1991). The present study's focus is on the classroom community as the students and their teacher interact and collaborate around reading, interpreting, and creating multimodal text. From sociocultural perspectives, cultural activities (e.g., scientific modeling) and tools (e.g., computers, language) are integral to knowledge building.

Methods and data sources

This study was conducted in one third-grade classroom with 32 students in a K-5 elementary school in the Midwest United States. Students were diverse with respect to race/ethnicity and academic achievement. On state achievement measures, only 20% of students demonstrated proficiency in ELA. The teacher was an experienced third-grade teacher and a second-year participant in the MLs research project.

Data sources included field notes, transcribed video of instruction, and artifacts. Informed by Brenner et al. (2009), observations and qualitative field notes focused on instructional events in which students were engaged in reading and using information from text to: discuss ideas, inform the development of artifacts, and synthesize ideas across texts and experiences. Focal lessons were videoed and transcribed. Artifacts included curriculum materials and student and whole-class work. Artifacts provided evidence of how students incorporated ideas from text in student- or class-generated products and provided insight into students' knowledge building and literacy development.

We use design-based research (DBR) (Brown, 1992) and case study (Stake, 1995) methods focused on the design, evaluation, and improvement of an intervention as it interacts with the contextual variables integral to enactment (Fishman et al., 2004). In this study, we analyzed the design and enactment of a set of texts and tasks in one MLs unit of instruction. Through analyzing multiple data sources and constructing in-depth cases, our goal was to uncover the features of the design and enactment of texts and tasks to identify how these supported or failed to support knowledge building and literacy development. Identification of missed opportunities and modifications provides evidence to support design revisions that might better support student learning in this context.

Analyses began with reading through transcript data line-by-line to identify relevant episodes of instruction and applying notes and codes responsive to our research questions. The next phase of analysis involved direct interpretation (Stake, 1995) of episodes within transcripts, and use of connecting strategies (Maxwell, 2013) to construct cases. This holistic examination of transcript episodes, designed curriculum, and related artifact data allowed us to uncover the ways in which the focal lessons unfolded – specific to the design and enactment of texts and tasks, and the ways in which students took up these opportunities – in order to develop assertions that were responsive to our research questions. Analyses supported our construction of narrative summaries to develop our case study report, in which we sought to maintain both the context and story of the ways in which instruction unfolded in the classroom during focal lessons (Maxwell, 2013).

Instructional context: The unit of instruction

To launch the unit, the teacher introduced the driving question and students viewed a video clip of Jurassic era organisms to identify similarities and differences between the organisms in the video and those that students see around their homes and school. Students then conducted observations of squirrels and other organisms in their habitats. Based on observations, students created initial models to explain how squirrels survive. In science, models are used to represent a system under investigation, develop explanations, make predictions, and communicate ideas (NGSS, 2013, Appendix F). Because this was students' first experience with modeling, their models took the form of concrete drawings of squirrels in their habitat (NRC Framework, 2012).

In the next set of lessons, students investigated squirrels' structures (e.g., teeth, tail, legs) by observing photographs, videos, and a squirrel's skull. The teacher then read aloud a text designed to introduce, describe, and engage students in making close observations of structures that enable squirrels to climb headfirst down trees. The researcher-designed text was paired with a video clip, illustrating the ideas in the text. After reading, the students returned to their initial models to make revisions to reflect new learning. After revising, students explored structure-function relationships of – and interactions among – organisms that share habitats with squirrels. Students selected and read one text from a set of researcher-designed texts, which provided written and visual information about a set of organisms found in squirrel's habitats (e.g., ant, coyote, tree). In small groups, students read and answered questions about the organism, drew and labeled organism structures, and identified interactions with other organisms. Students then used this information to co-construct a class model to explain interactions among the organisms in an ecosystem.

Findings

In this section, we describe findings from our analyses of the design and enactment of two sets of texts and tasks.

For Squirrels, It's Headfirst and Down and paired video: Design and enactment

For Squirrels, it's Headfirst and Down was designed to: (a) illustrate core ideas related to adaptations that enable organisms to survive in particular habitats, (b) provide information that built upon students' first-hand observations, (c) include multimodal features (written text and images), and (d) motivate and provide new information to support engagement in scientific modeling based on new learning. The paired video was selected to illustrate the ideas in the text and to provide an opportunity for students to observe a squirrel using the structures depicted in the text and photographs. We found that the design of the texts and tasks, and the teacher's enactment, synergistically supported third-graders' science and literacy learning. We also identified missed opportunities, within the design of the curriculum and enactment, for further supporting the science and literacy learning of all students.

Before reading: Setting the purpose and preparing to read

The teacher leveraged the text and task to support students' science and literacy learning by supporting students to: (a) connect to prior knowledge and experiences, (b) identify the purpose of the text and task, and (c) make predictions prior to reading. The teacher began the lesson by asking students to recall their recent experiences in the PBL unit, which included priming students' thinking about squirrels' structures investigated during previous lessons using multiple modes of representation (photographs, videos, skeletons). Specific to literacy learning, supporting students to activate prior knowledge before reading creates opportunities for students to draw on related knowledge and experiences to interpret new information in text (Brown, Pressley, Van Meter, & Schuder, 1996). In this case, students' prior knowledge was shared knowledge the class developed through analyzing multiple modes of representation.

One purpose for reading this text was to provide new evidence that students could add to their models, in order to explain squirrel survival. After prompting students to think about their earlier observations and investigations, the teacher explained, "We're going to read this together, but as we're reading, I'm going to ask you some questions. And then we're going to…look at our models." This excerpt illustrates how the teacher connected the purpose of the reading to the modeling task. In research investigating teachers' differential enactments of an inquiry curriculum, Puntambeker, Stylianou, and Goldstein's (2007) findings emphasized the teacher's role in helping students understand connections among instructional activities and concepts in order to drive student learning.

During reading: Supporting students to read and interpret information

During the interactive read aloud, the teacher supported students' reading and interpretation by: (a) engaging students in visualizing and acting out the ideas in the text, and (b) checking for understanding. After reading a section that described how squirrels use their sharp claws to grip a tree ("With its sharp claws, a squirrel can grip the bark of a tree. The strong grip of the front claws allows the squirrel to hold on while it moves its back feet. Then, the back feet can hold on while the front feet move."), the teacher asked students to "picture" the description in their mind. The teacher reread this portion of the text and made several gestures, which multiple students imitated, to demonstrate the squirrel's movement. This echoes Glenberg's (2010) findings that one way to enhance reading comprehension is by supporting students to make connections between the text and its embodied meaning.

The teacher also paused frequently to check for understanding as the class read the text aloud together. Her questions focused on the meaning of the words in the text as well as supporting students to analyze and interpret information in photographs. In one example, the teacher paused and, as prompted in the text ("Look closely at the back feet of the squirrels in these photographs."), asked students to closely observe two photographs.

Teacher: *[Reading aloud]* "To find out about the last feature that helps squirrels to climb down the tree headfirst, look closely at the back feet of the squirrels in these

	photographs." … you should be on those two pictures…they're telling you to look closely at what?
Kaylee:	The pictures!
Student:	The squirrels.
Student:	The feet.
Student:	The back feet.
Teacher:	The back feet. They're specifically telling you to look closely at the back feet… What did you notice about those back feet, Jessica?
Jessica:	I noticed that the tree one is actually like hanging upside down on the tree and the other claws are just leaning on it.
Teacher:	Okay, so it's hanging upside down… What else do you notice about him, Aiden?
Aiden:	That I notice that it's not exactly hanging down. It's actually using its back feet to push off and using its front feet also to push off.

In this excerpt, the teacher asked students to study the photographs and invited them to share their observations. The teacher then guided students to clarify what, specifically, they should examine in the photographs (i.e., squirrels' back feet). After clarifying, the teacher invited students to share their observations before continuing to read the text.

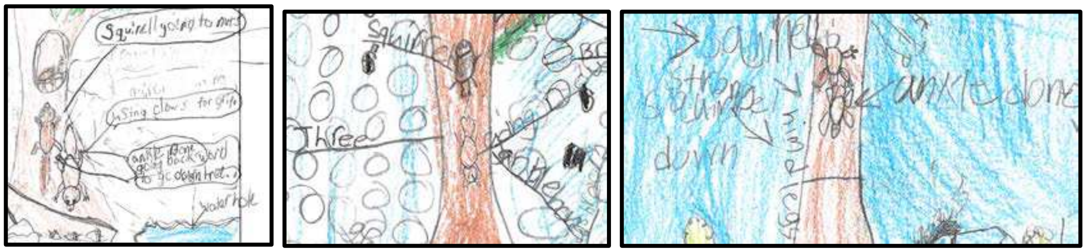
After reading: Using information from the text to inform revisions to scientific models

The teacher used the text and task to scaffold students' science and literacy learning by supporting students to identify and use text ideas to revise models in whole-class, small-group, and one-on-one contexts. The teacher also leveraged the text and task to scaffold students' understanding of and engagement in scientific modeling.

After reading, the teacher made a number of instructional moves to scaffold students' use of the information in the text to inform revisions to their models. For instance, immediately after reading, the teacher prompted students to apply the reading to the modeling task and asked students to summarize the structures that squirrels use to climb headfirst down trees. The teacher then played a video clip of a squirrel climbing and leveraged this as another opportunity to illustrate the structures students read about using a different mode of representation (e.g., Teacher: "Look how its…back leg is completely turned around." Brody: "I can see it!"). Once students began revising their models, the teacher scaffolded their use of information from the text, photographs, and videos by conferring with individual students, inviting them to share their revisions with the class, and guiding them to integrate visual and written modes of communication with their models.

Teacher:	Oh, Ellie's adding something… Ellie, what are you adding?
Ellie:	I'm adding…another squirrel in the position that it can be.
Teacher:	Okay, you're adding another squirrel, and you're putting it in what kind of position? Can you describe that for me?
Ellie:	In the position going down where its legs are facing backwards and its front paws are facing forward.
Teacher:	…what else could you do in your models once you've drawn that squirrel…?
Sam:	Label.
Teacher:	Label it. Label the back legs. What specifically would you label, Sam?
Sam:	Claws.
Teacher:	Okay, it has claws. What else does it have? Aiden?
Aiden:	It has an anklebone.
Teacher:	It has an anklebone, right? Those are the structures that allow it to go headfirst and down.

This excerpt illustrates how the teacher used an individual student's model to launch continued review and discussion of the structures introduced in the reading. Also, one purpose of scientific models is to communicate ideas to others (NGSS, 2013, Appendix F). This example illustrates how the teacher used Ellie's model to introduce the idea of combining labels and drawings to clearly communicate science ideas. Figure 1 (a) shows a portion of Ellie's model. After the above exchange, Ellie added labels for the squirrel's anklebone and claws.



(a) (b) (c)

Figure 1. Ellie's model (a) includes drawings and labels. Jenna's (b) and Malik's (c) models provide more examples.

On the second day of enactment, the teacher continued to scaffold students' use of the information in the text to inform revisions to their models by (a) sharing and discussing additional students' models, (b) frequently directing students' attention back to information in the text, and (c) clarifying the purpose of the modeling task.

Constraints of the text and task revealed through enactment

Specific to our second research question, one limitation was the written curriculum's lack of guidance for engaging students in text-based discussion. While the teacher frequently paused to check students' understanding of images and words, many questions did not elicit high-level thinking, which is important for supporting comprehension in the context of discussion (Soter et al., 2008). Further, both the written curriculum and the teacher's enactment missed opportunities for students to integrate ideas in the text with related activities, such as investigations and observations, done prior to reading. This echoes Prain and Waldrip's (2006) finding that teachers did not systematically support students to translate across modes. These findings suggest that teachers may benefit from additional support to enact text-based discussions, particularly when reading tasks call for translating across modes and making connections to related unit activities. In revisions, we have begun to design more interactive reading guides (Arias, Palincsar, & Davis, 2015) to support students' discussion and sense-making with multimodal texts in our PBL units.

Structure-function cards and paired map: Design and enactment

The organism structure-function cards were designed to: (a) illustrate core ideas related to adaptations that enable organisms to survive in a particular environment; (b) provide information that connected to and built upon students' first-hand observations within and beyond the classroom; (c) include multimodal features (written text and images), and (d) motivate and provide information to support students' engagement in the practice of scientific modeling. In the focal classroom, students used digital versions of the structure-function cards, accessed via Chromebooks. Also, a paired digital map (Google Map of the area around the students' school) was selected to engage students in using their class interactions model to make predictions about organisms that live and interact in a local context. We found that the design of the texts and tasks, and the teacher's enactment of the organism structure-function cards synergistically supported third-graders' science and literacy learning. Again, we found missed opportunities, both within the design of the curriculum resources and the enactment of the lessons, for further supporting science and literacy learning.

Before reading: Setting the purpose and preparing to read

Analysis of the written curriculum and transcripts of classroom enactment revealed that the teacher leveraged the texts and task to support students' science and literacy learning prior to reading by: (a) supporting students to activate prior knowledge, (b) clarifying key vocabulary, and (c) setting a clear purpose for reading.

During reading: Supporting students to read and interpret information

The teacher leveraged the texts and task in support of students' science and literacy learning by supporting students to read and interpret information in the texts. Students' partner reading and interpretation of their chosen structure-function text was scaffolded by the guiding questions included in the curriculum materials and the teacher's use of the questions as she conferred with individual and small groups of students about their reading and learning with text.

During reading, students worked with a partner or group to respond to a set of guiding questions as they read text and analyzed images about their organism. The guiding questions were: (1) *What is your organism?* (2) *List the structures you read about.* (3) *Choose one of the structures you listed. How does this structure help the organism meet a basic need?* (4) *Does your organism live in the same environment as squirrels?* (5) *What foods does your organism need to survive?* (6) *What predators eat your organism?* These questions were designed to support students to identify information about how their organism interacts with other organisms in its habitat, in order to support the co-construction of the organism interactions model. In one-on-one, small group, and whole-class conversations, the teacher used the guiding questions to support students to read and interpret multiple modes (i.e., text, photographs).

Analysis of students' responses to guiding questions provided additional evidence of how the questions scaffolded students' reading and interpretation of the organism texts. While ten of sixteen focal students completed all six questions, all focal students identified their organism, listed structures, and described how one of those structures enables the organism to survive. The NRC Framework (2012) explains that, "The quality of a student-developed model will be highly dependent on prior knowledge and skill and also on the student's understanding of the system being modeled" (p. 59). In other words, the quality of the class-developed interactions model depended on students' prior knowledge and understanding of the environment as a system, including the organisms that are a part of that system. We argue that, in hand with students' firsthand observations and investigations, the multimodal information in the structure-function cards and the scaffolding provided by the guiding questions supported students to build the prior knowledge necessary to co-construct their organism interactions model as a class.

After reading: Using text information to inform construction of the interactions model

After reading, the teacher used the lesson plans, texts, and task to scaffold students': (a) sharing of learning from text to develop shared knowledge, (b) use of shared knowledge to co-construct the interactions model, and (c) application of the model to explain organisms' interactions in a local context. The teacher provided opportunities for students to share what they learned about their selected organism with the rest of the class. This was important because, in order for students to co-construct a model to explain how organisms in the environment interact, the students needed to build shared knowledge about the organisms. After responding to the guiding questions, the teacher invited students to debrief their findings. To conclude this day of enactment, two groups had the opportunity to: (a) present their learning by sharing their responses to the guiding questions and also (b) show the class how they navigated and identified information in the digital text (e.g., tapping to select the text, scrolling to locate information).

On the next day of instruction, the teacher introduced the *interactions* modeling task, and students used what they had learned about their organism to create a small drawing, on which they labeled one or more of the organism's structures and described how it interacts with squirrels. After completing this step, each group shared and taped their organism card on the chart paper where the class would co-construct the interactions model. After attaching the cards to the chart paper, students had additional opportunities to share their learning about the organisms' structures and how the organism interacts with squirrels (e.g., the coyote is a predator of the squirrel). Transcripts of whole-class discussions revealed that the students were developing shared knowledge of the different organisms, structures that enable them to survive in their environment, and ways in which they interact with the squirrel and other organisms.

The teacher supported students to leverage their learning from the readings to co-construct the interactions model, and asked students to suggest ways they could represent and communicate interactions among organisms. Initially, students proposed that they could "look on the Chromebook" to show relationships," "act it out," or "write it." The teacher pressed students to think of ways they could clearly communicate the relationships among organisms directly on the chart paper. The design of this modeling task and the way in which the cards were arranged on the chart paper called for students to create a more abstract representation than the previous squirrel environment models, in which students drew and labeled concrete pictures. As the teacher pressed for more ideas, one student proposed that they could draw and label lines between organisms to communicate the nature of their relationships (e.g., predator/prey, shelter, etc.), a proposal which was taken up by the class.

Zayn:	Line with the squirrel to the red-backed salamander. The squirrel is a predator…
Teacher:	The squirrel is a predator to the red-backed salamander…what's the special structure that the salamander has that allows it to get away…?

Zayn: Its tail.

Teacher: What does its tail do? …Go ahead, Zayn.

Zayn: Falls off so it can run away, and once it run away, far away, it grows a new one.

This excerpt illustrates the ways in which the teacher enlisted students' contributions in order to co-construct the interactions model to explain relationships among organisms in a habitat. Understanding and being able to explain the organisms' unique structures and their functions, supported students to co-construct representations of complex interactions among the organisms included in the model (see Figure 2, below).

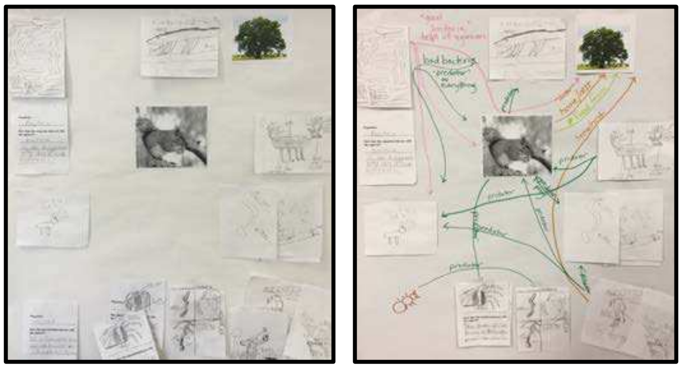


Figure 2. Co-constructed interactions model prior to and after identifying and labeling organisms' interactions.

After constructing the interactions model, the teacher extended the written curriculum by engaging students in analyzing a digital text – a satellite view Google Map of the area around their school – and in using their model to make predictions about where on the map students might find squirrels and why. Prior to asking students to use their model to apply the phenomenon under study, she first supported students to interpret the map more generally ("Tell me what this is a map of. How do you know? What do you see?"). While the digital satellite map was an unfamiliar mode to students, they were able to draw on prior knowledge of landmarks and buildings because the map represented an area with which all students were familiar. After completing an initial "reading" of the map, the teacher asked students to make connections between the model and the environment around their school ("Based on our interactive map [and] based on what we know about squirrels and their environment…where do you think we would be able to find the most squirrels?"), and supported students to use evidence from the model and their firsthand experiences to make predictions about organisms they might find in the area (e.g., frogs, coyotes, etc.).

Constraints of the text and task revealed through enactment

One limitation of the written curriculum, revealed in analyses, was the lack of science content knowledge supports for the teacher to facilitate enactment of the organism text-reading and modeling task. Analyses revealed two instances, in the context of clarifying vocabulary before reading, when enactment may have contributed to confusion among students about what does and does not qualify as an organism. One potential contribution of providing educative curriculum materials, such as interactive reading guides, is to enhance teachers' content knowledge (Arias, Bismack, Davis, & Palincsar, 2016). Providing this type of information in future iterations of the curriculum may better support teachers to scaffold students' understanding of science vocabulary and concepts prior to, during, and after reading.

Significance

This work is significant because, as Lemke (2004) urged, students need to be able to interpret, analyze, and produce multiple modes of representation in service of disciplinary knowledge building. Aligned with the 2018 conference theme, this work also helps us to understand the grainsize at which we need to study teachers' practice in order to *unpack the complexity of the learning and teaching process.* In the present study, this complexity is revealed through analyzing teacher discourse, teacher-student interactions, and students' use and development of multimodal texts. Additionally, characterizing students' opportunities to learn requires the close analysis of teaching and learning in real-world settings (Litman et al., 2017). This kind of analysis can support curriculum designers to engineer opportunities to learn that are different from those typically offered in K-12 classrooms, and to more fully support teachers in managing the complexity of maximizing all students' opportunities to learn in diverse classroom settings.

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