The Use of Teacher Resources in a Sheltered Science Unit on Watersheds

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Abstract

This article examines the ways in which four focal English Learners (ELs) in an eighth-grade sheltered science classroom used visual and written resources in a unit on watersheds. The students first recorded their observations about stream tables through open-ended drawing and writing. Their own ideas were evident in these responses, but subsequent tasks directly referenced photocopied visual material. As a result, the students directly replicated the distributed diagram and graphic organizer. This impeded conceptual cohesion across the unit as reflected in the students' visual and written responses to tasks that were based on teacher-provided resources. This article concludes that, in sheltered science classrooms, visual and written modes must be enlisted as meaning-construction resources, not simply as meaning-reproduction resources, if they are to mediate science understanding.

Introduction

The problematic nature of science learning for English Learners (ELs) in the United States is evidenced by data from the National Assessment of Educational Progress (NAEP). In 2015, 69% of non-EL eighth-graders scored at the basic level or higher on the NAEP science assessment; in contrast, only 19% of ELs scored at the basic level or higher for the same assessment (NCES, 2015). Clearly, there is a need to improve science instruction for ELs nationwide.

In science classrooms, teachers communicate concepts to ELs through academic or scientific language that students are expected to use during science activities. Consequently, learning is impeded for those ELs who are not proficient with such language (Dutro & Moran, 2003; Honeycutt Swanson, Bianchini, & Lee, 2014; Lyon, Bunch, & Shaw, 2012). An inquiry-based approach, however, can support both science learning and English language development by contextualizing the domains in which English develops: speaking, listening, reading, and writing (e.g., Lee, Maerten-Rivera, Penfield, LeRoy & Secada, 2008). A critical aspect of this support, however, is the way in which ELs use teacher-provided resources during inquiry science activity (Lee, Quinn & Valdés, 2013).

Multimodal science activity generates meaning-making by both students and teachers through a variety of resources beyond oral language, including written language, imagery, and physical models (Hubber, Tytler, & Haslam, 2010; Jewitt 2013; Kress, 2009; Zhang, 2016). These modes work together to help students at all English language proficiency (ELP) levels to clarify and communicate what they understand about the science materials and phenomena with which they engage. A central tenet undergirding this approach is the fact that meanings are "very differently configured in writing or in speech, in gesture or in image" (Harste & Kress, 2012, p. 208). Thus, students whose writing shows less precision in terms of content-specific vocabulary may accurately detail science concepts visually by making use of the potential of space (Grapin, Llosa, Haas, Goggins & Lee, 2019; Harste & Kress, 2012). In this paper, we examine how ELs used teacher-provided resources to represent science meanings both visually and through written language in a unit on watersheds as implemented in an eighth-grade sheltered science classroom. We question how ELs used teacher-provided resources to represent their ideas about watersheds through these two modes.

Framework

The Next Generation Science Standards (NRC, 2012) stress the importance of models as tools that ELs can use to represent and explain the natural world, to develop scientific and language understandings, and to make sense of experience (Brooks, 2009; Kress, Jewitt, Ogborn & Tsatsarelis, 2001; Mavers, 2011). In sheltered classrooms, where instruction is tailored specifically to ELs (Wright, 2015), simply providing students with opportunities to engage with science materials is not sufficient to support either English use or the development of science understanding

Keywords: English Language Learning, Sheltered science learning, Visual literacy, ELL writing, Watersheds

(e.g., Harper & de Jong, 2004; Lee and Luykx, 2007; Peregoy & Boyle, 2017). Some research has addressed the nature of multimodal science teaching and learning specifically for adolescent ELs (e.g., Kress et al., 2001; Lee et al., 2013; Márquez, Izquierdo & Espinet, 2006; Richardson Bruna, 2009; Villanueva, 2016). For example, the teacher's use of a range of modes supports an enactment of meaning-making in which each mode "enables the unfolding of a different view" of the science content (Kress et al., 2001, p. 46).This suggests that a multimodal approach would support ELs' science learning by expanding the sorts of opportunities that are made available to access meaning. But what does such an instructional approach look like? How do ELs engage in a multimodal approach to learning science?

Villanueva (2016) found that in South African grade 12 classrooms specifically for second-language learners, students often copied text from the blackboard using bullet points or short, incomplete entries in their science notebooks. Strikingly, although the use of student drawing was not heavily promoted, nearly two-thirds of the students' entries contained original drawings. Over half of the students' drawings gave attention to labeling and materials as well. But if visual response takes a secondary role to written language, it may function only as a substitute mode to be used in case students have difficulty expressing themselves in writing.

While the multimodality of the teacher's approach to the science discourse itself can be countered by students, it also impacts student evaluation and achievement. In fact, teachers often construct their own discourses "through a considerable amount of communicative resources they are not completely aware of," including gesture, graphic signs, and visual language (Márquez et al., 2006, p. 223). While it is important for the teacher to "support language use and development in the service of making sense of science" (Lee et al., 2013, p. 231), a social semiotic perspective recognizes that every discourse participant is a sign-maker. Further, because many scientific concepts "acquire meaning thanks to the specialized collaboration between modes," multimodal discourse helps ELs to move from physical experiences with science materials and phenomena to a more abstract conceptual level (Márquez et al., 2006, p. 221). This, in turn, permits the representation of increasingly complex concepts (Márquez et al., 2006). Thus, if students are to induce a connection between language and inquiry activity, modes must be enlisted as meaning-*construction* resources, not simply as meaning-*reproduction* resources. The aim is for ELs to develop a conceptual identity in the context of the science discourse (Britsch, 2020).

By taking a social semiotic perspective, then, the study reported below viewed the science classroom as a multimodal context in which the participants mediate the environment through the use of various semiotic resources such as drawings and diagrams, oral language, written language, movement, and physical models. Further, the "potentials and limitations" of each mode represent the interest of the sign-maker at the point of making that sign (i.e., those aspects of the discourse that are most salient to that sign-maker) (Kress et al., 2001, p. 1). Even when teacher-selected or teacher-made materials serve as resources, a social semiotic approach awards students an agentive role in the shaping of meanings as they make sense of and explain science phenomena (Johnson-Laird, 1983; Kress, 2003). Students make their thinking explicit multimodally in light of their developing conceptual models (NRC, 2012).

We focus primarily on teacher and student use of visual communication that incorporates written language. As such, both modes are "loaded with meanings" (Machin, 2007, p. 21). In a sheltered classroom, the aim is not to supplant either mode with the other. Because "meanings are always made with more than one mode" (Bezemer & Kress, 2008, p. 171), visual learning is viewed as vital to the representation of knowledge (Kress, 2003; Mavers, 2011). In fact, science literacy for ELs centrally requires the ability to engage in the manipulation of "…symbols representing elements of the internal or external environment by using imagery" (Seels, 1994, p. 106). Images themselves are defined as "mental pictures of sensory experiences, perceptions or conceptions" (Seels, 1994, p. 106). Thus, while modes may *denote* particular environments or objects, they also *connote* ideas (Machin, 2007, p. 21). By taking a multimodal, social semiotic view, we focus—not strictly on denotation—but also on connotation: what kinds of ideas or understandings are "communicated through that which is represented and through the way in which it is represented" (Machin, 2007, p. 25) in the science discourse?

Method

This four-month study was carried out in an eighth-grade, public school, sheltered science classroom enrolling ELs from entering to bridging levels of English language proficiency (WIDA, 2007). Sheltered classrooms enroll only ELs with the aim of providing instruction that simplifies language demands while still addressing grade-level content (Wright, 2015). The three-week watershed unit was selected because it incorporated the use of a physical model (stream tables), data collection (water tests), student writing and drawing, and group posters. A social semiotic approach is in keeping with the method used for this study because it defines all of these modes as meaning-making resources. On this view, written language is not a set of prescriptive rules but a tool for communication; drawing is not the reproduction of a model but a resource for sign-making (van Leeuwen, 2005). Thus, this study took a naturalistic approach in that we manipulated neither the classroom instruction nor the teacher's and students' participation in that instruction (Patton, 2002). Our methods were designed to capture day-to-day events, interactions, actions, and uses of semiotic resources by the teacher and students. The data sources consisted of (1) video-recordings and transcriptions of each day's interactions (transcribed by a native speaker of Spanish when utterances were in the students' L1), (2) photocopies or photographs of written and visual products, (3) photocopies of teacher handouts, (4) *The Watershed Tour* (LaMotte, 2000), and (5) researcher field notes to contextualize daily events as well as activity outside the camera frame.

A process of qualitative, social semiotic analysis was used to identify and clarify patterns of activity in the data (Bogdan & Biklen, 1982; Jewitt & Oyama, 2001; Kress & Van Leeuwen, 2001). We then constructed interpretations and developed a case record from which the case study was written. We present this case study narrative as a "descriptive picture" or "holistic portrayal" of four English Learners and their teacher as they engaged in the watershed unit (Patton, 2002, p. 450).

School Site

The school was located in a Midwestern metropolitan area of approximately 70,000 residents. It had a 20% enrollment of Latinx students; 10% were ELs. Approximately 65% of the students at the school received free or reduced lunch. Slightly over one third (39%) of the eighth-graders in the school did not pass the state standardized tests during the academic year during which the study was conducted, with 33% not passing the English Language Arts component of the test and 24% not passing the math component.

Participants

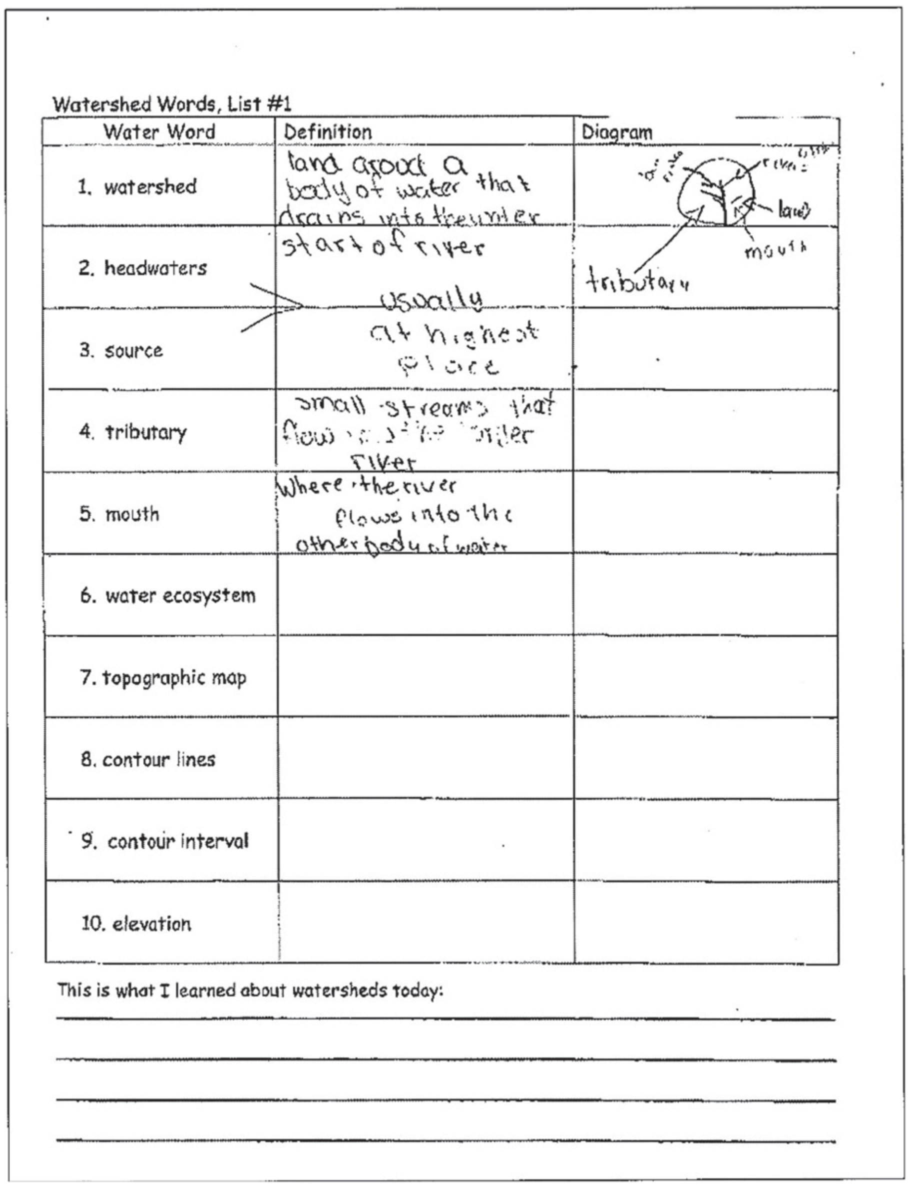
The four focal students were selected in collaboration with the teacher to represent a range of ELP levels based on the standardized language assessment instrument used by the school district (see Table 1). The focal students worked well together in the teacher's view. The focal group did not include students with developmental delays or other special needs. Both student assent and parental consent were obtained.

Table 1. Student Participants and their English Proficiency Levels

Student Pseudonym	Speaking/ Listening	Reading/ Writing
Beatriz	5/4	4/3
Salvador	4/4	3/3
Humberto	4/4	3/3
Graciela	1/1	1/1

The teacher had been teaching science for 10 years and held a master's degree in science education. The teacher had volunteered to work with ELs at the school. Prior to this study, the school district had provided a two-day training workshop based on the Sheltered Instruction Evaluation Protocol (SIOP) (e.g., Echevarría & Graves, 2011). The training was conducted by the ESL coordinator from another school district. There was no relationship or interaction between the workshop provider and the researchers.

The teacher invited the researchers to study the class due to an interest in teaching effectiveness. One of the researchers is a specialist in English Learning and visual literacy and the other is a science educator specializing in environmental science. The researchers functioned as participant observers but did answer teacher questions, if asked. The teacher was under no obligation to consider any of the researchers' responses in any respect. At the teacher's request, one of the researchers provided the teacher with


Watershed Words, List #1

Water Word	Definition	Diagram
1. watershed	land around a body of water that drains into the river	river, land, mouth, tributary
2. headwaters	start of river	
3. source	usually at highest place	
4. tributary	small streams that flow [illegible] the bigger river	
5. mouth	Where the river flows into the other body of water	
6. water ecosystem		
7. topographic map		
8. contour lines		
9. contour interval		
10. elevation		

This is what I learned about watersheds today:

Figure 1. Teacher's Key Vocabulary List.

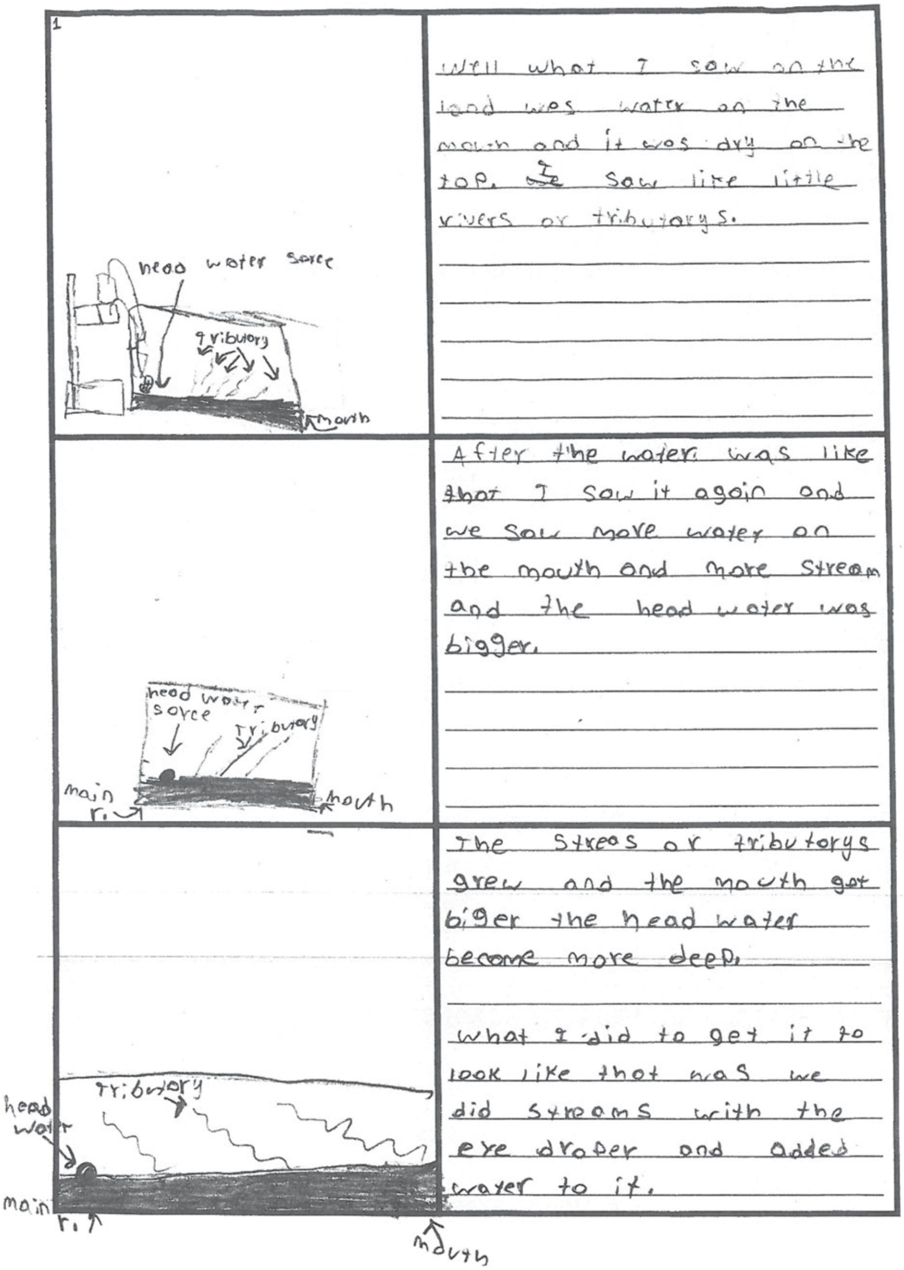


Figure 2. Humberto's Stream Table Worksheet.

The Watershed Tour (LaMotte, 2000, subsequently referred to as "the kit") to plan the science instruction, but this did not include direction on how to use the kit. The teacher selected portions of the kit to use as a resource for science content and for teaching the unit.

The Case Study

The aim of the unit reported below was to "introduce students to stream and river ecosystems …water quality, and how their own actions can affect a watershed" (LaMotte, 2000, p. 3). The teacher's implementation of the kit-based portion of the unit addressed the following objectives:

- label and define the parts of a watershed (i.e., mouth, source, tributary, headwaters) (LaMotte, 2000, p. 12);
- identify a watershed (LaMotte, 2000, p. 22);
- compare and contrast land uses at the "Big River Watershed" sites (LaMotte, 2000, p. 22);
- investigate how land use affects water chemistry (LaMotte, 2000, p. 42).

Poster 1: Observing and Representing Stream Tables

The teacher began by frontloading the key vocabulary shown in Figure 1, writing out the definitions for "watershed, headwater, source, tributary" and "mouth." The teacher then distributed a packet of photocopied visual and written materials. The cover page showed an image of the "Big River Watershed" with its headwater, mouth, and tributaries as well as the visual elements characterizing four fictive sites: "Mill Creek," "Pine Creek," "Muddy Run," "Big River" (LaMotte, 2000, p. 29). The teacher directed the students to set up a stream table as a physical model of the "Big River Watershed." The focal students added objects to represent different elements depicted in the photocopied image (e.g., sticks for trees).

The next day, the students added water to their stream tables and made observations as the water flowed. To record these, the students completed a teacher-prepared worksheet that consisted of blank boxes for drawing and lined boxes for writing. The teacher instructed them to "draw what you see" and to include labels from the key vocabulary list. This open-ended prompt and the blank space for drawing required the students to represent a three-dimensional physical model in two dimensions. The students did this in different ways; the observation worksheet completed by Humberto is shown in Figure 2.

Humberto visually related his experience with the stream table, as well as the components of the apparatus itself, in close detail. His first drawing represented the stream table model itself, showing its physical set-up on the left and the directionality of the water on the right. Because the point at which the water fell from the apparatus did not align with the direction in which the tributaries flowed, Humberto used different points of view for the two sides of the drawing. This enabled him to show

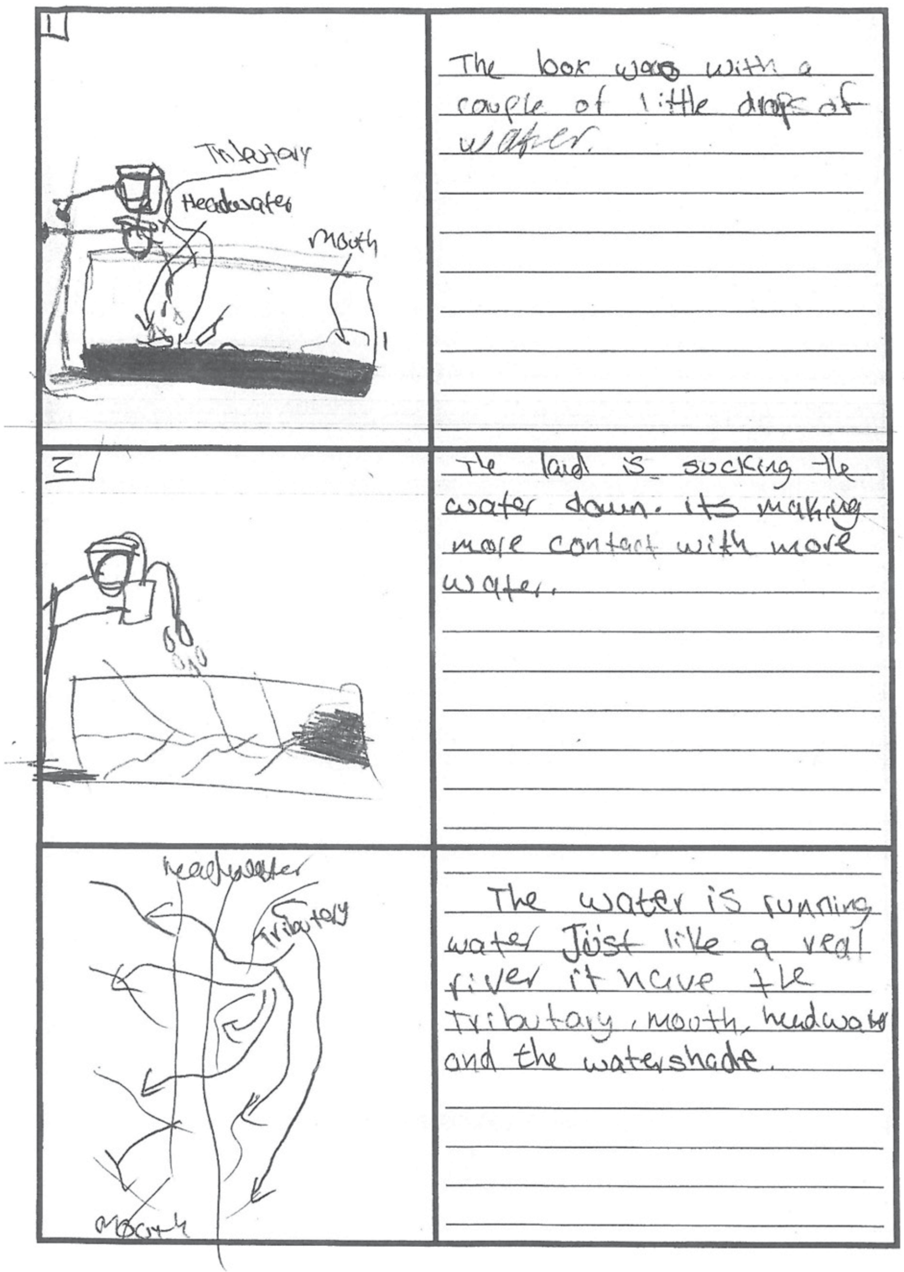


Figure 3. Salvador's Stream Table Worksheet.

the tributaries and to demonstrate that he understood the movement of water from the tributary to the mouth of the main river. His second drawing eliminated the stream table mechanism and abstracted the components of the watershed as contained within the box. The third drawing eliminated even more detail, deleting the "box" boundary to take a wider, and accurate, view of a watershed. His written language incorporated the key vocabulary as appropriate to describe the changes he saw; for example:

> After the water was like that I saw it again and we saw more water on the mouth and more stream and the head water was bigger.

His writing also characterized his own actions in carrying out the investigation:

> What I did to get it to look like that was we did streams with the eye dropper and added water to it.

Humberto used drawing to relate the components of the stream table to the watershed and writing to describe his own process. Together, this communicated his understanding that a watershed is made up of streams and that a river has a headwater, a mouth, and tributaries. Similarly, Salvador produced detailed drawings beginning with the set-up of the stream table, labeled with key vocabulary words (Figure 3). The apparatus remained but was simplified in his second drawing to represent the water flowing through the stream table. His third drawing situated this process in the context of a watershed, labeled with the same key vocabulary items. Unlike Humberto, Salvador's text described a portion of the set-up but did this quite literally:

> The bar was with a couple of little drops of water.

The second text box described the ongoing process:

> The land is sucking the water down. Its [sic] making more contact with more water.

The third text box reiterated the same three vocabulary words Salvador had used in his first and third drawings, but used them to explain why the stream table was like a real river:

> The water is running water. Just like a real river it have the tributary, mouth, headwater and the watershade [sic].

Thus, while Salvador's drawings accurately detailed the relationship between the stream table and the watershed, his writing described what happened by combining colloquial terms with scientific vocabulary in a direct, almost telegraphic, way.

In contrast, Beatriz's first two drawings presented a three-dimensional rendering of the stream table: a semi-abstract view that depicted the apparatus in a simplified way, including just the essential elements. Her third drawing moved to a wide view of the watershed itself (Figure 4). She did not label her drawings with any of the key vocabulary, but her written language iterated the students' process in carrying out the investigation. She used only one key vocabulary word, "tributary," along with colloquial terms to state, for example, that adding water made the river deeper:

> When we make more tributary and we drop more rain to it and that makes the river more drown.

Thus, Beatriz's drawings showed that she understood the structure and water movement in a watershed, while her writing labeled and described. Graciela's drawings were more detailed than Beatriz's. She used them to define the formation of the watershed, representing it first as separate land/water components, then defining the river and finally its tributaries (Figure 5). She labeled these views with colloquial words and used the text, as had Beatriz, to describe the students' own activity with the stream table; for example:

> In the land we makes [sic] a river we putting water in the river. That looks a river.

Graciela also described the branching of the stream (i.e., tributaries) by making an analogy with a tree:

> In the land we make a river after we make like a tree, add more water in the river tree.

In general, the students' drawings were more precise than their writing, conveying their own perspectives, largely accurate, of their observations. Drawing allowed Graciela to represent and communicate understanding that would have been difficult to do in writing. As level 3 writers, Salvador, Beatriz, and Humberto were able to use some specific content area language in sentences that contained syntactic errors but kept the semantic sense intact (WIDA, 2007, p. RG-45).

After the stream table activity, the teacher instructed the students to begin Poster 1 (Figure 6), asking them to "draw the river and use the four vocabulary words" (i.e., mouth, tributary, headwater, watershed). Not only were these directions

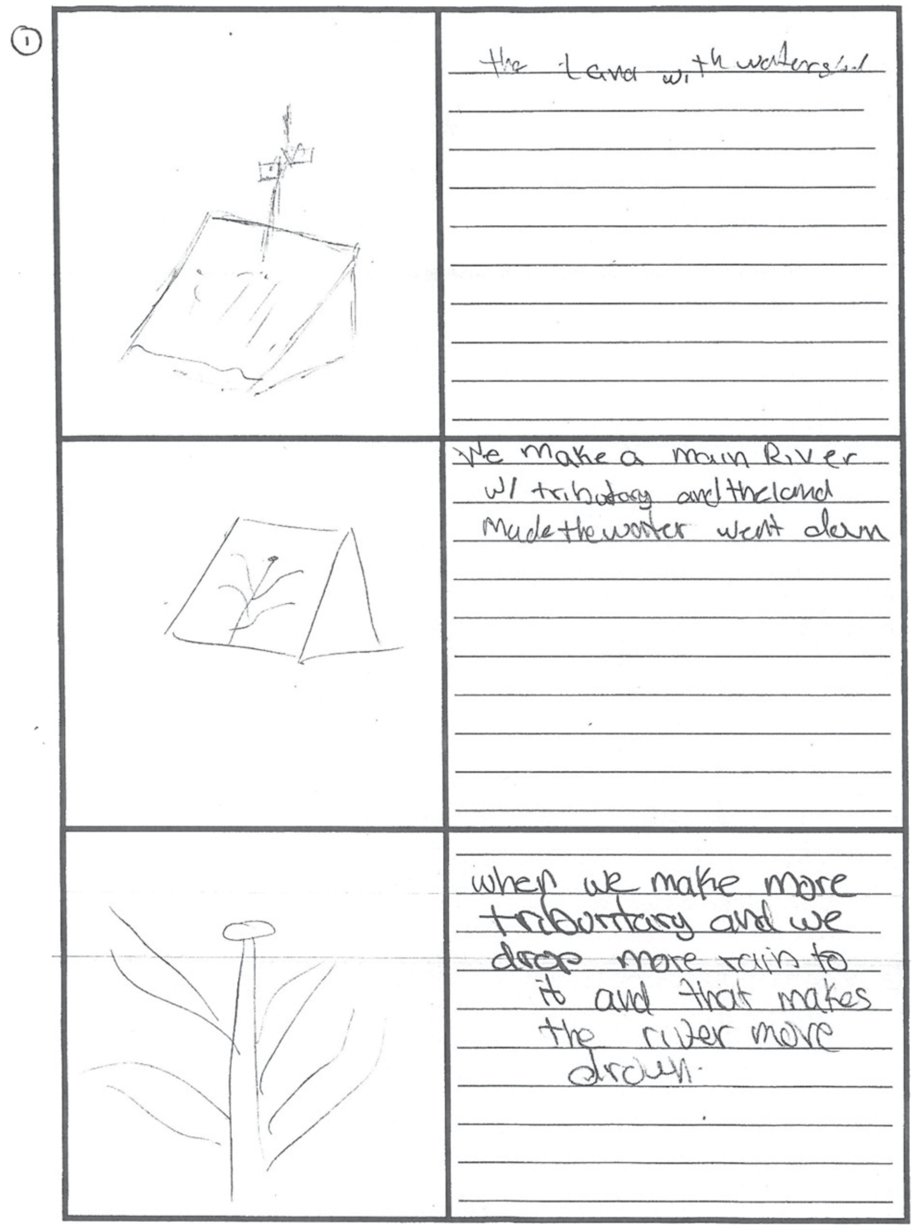


Figure 4. Beatriz's Stream Table Worksheet.

more closed-ended than those for the stream table worksheet, but the teacher also referred the students directly to the line drawing of the Big River Watershed from the packet of photocopied materials. As a result, the students' drawing directly replicated the distributed image and used three of the frontloaded vocabulary words, ignoring "source" and "tributary," although both were depicted. The students drafted the curvilinear outline of the river and used pictographs to indicate the buildings and parking lot for Mill Creek Mall, a line of trees for Pine Creek, a red square (i.e., a barn) for Muddy Run, and a row of rectangles for the Springfield urban area in the Big River site. After drawing, the students added written language for labeling alone: the poster title (i.e., "Big River Watershed") and the labels for all four sites (i.e., "Mill Creek, Pine Creek, Muddy Run, Big River") as well

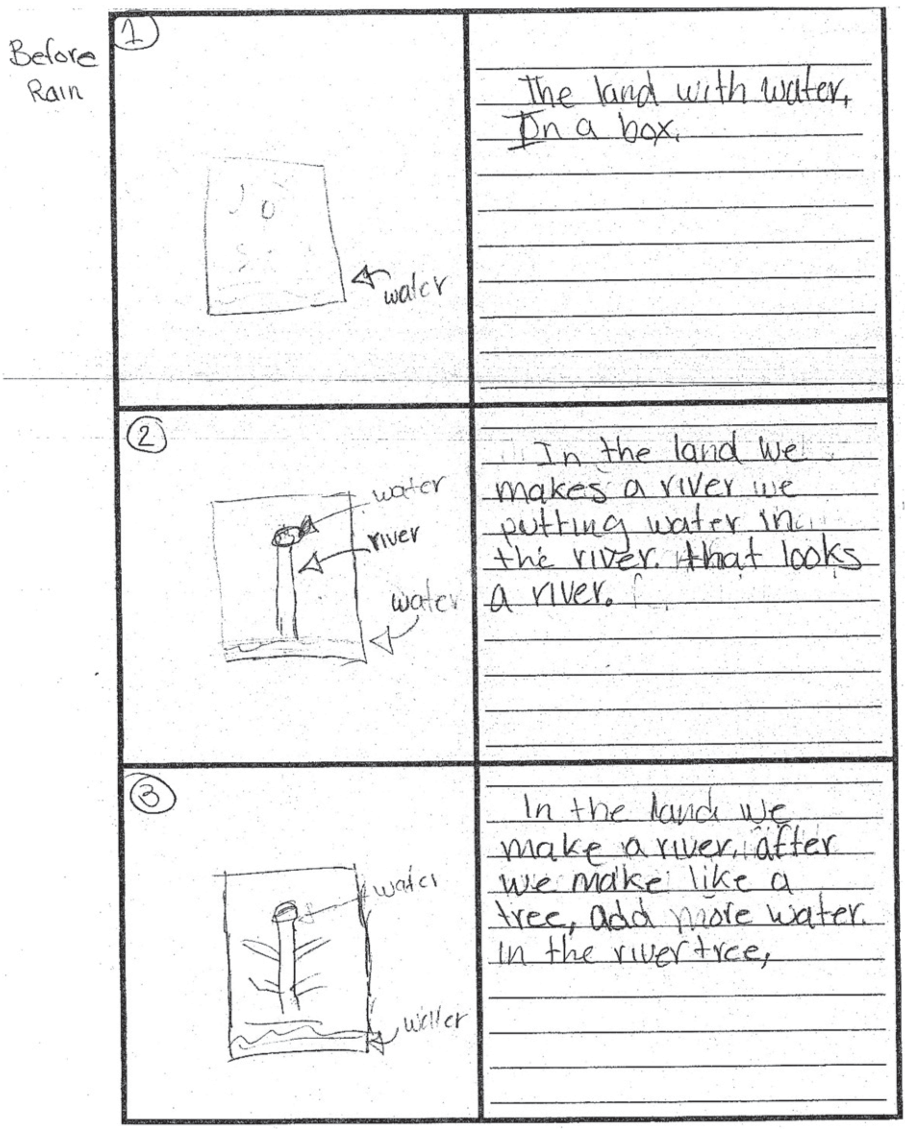


Figure 5. Graciela's Stream Table Worksheet.

as two other locations ("Mill Creek Mall," and "Springfield"). They added the label "Buildings" and copied two of the words from the key vocabulary list: "headwater" and "mouth." This omitted any visual reference to the flow of water through the watershed, despite the students' recent experience with the stream tables. Thus, the poster did not reinforce the concepts that the students had begun to articulate on their stream table worksheets. They instead carried out the poster task as new content and used a copying approach to complete it.

Posters 2 and 3: Water Testing, Organizing and Communicating Data

Next, the students completed water tests for each site in the Big River Watershed using water samples that matched the characteristics of each site in the watershed. The focal students each received a handout for their site, Mill Creek (LaMotte, 2000, p. 35), which visually detailed it through pictographs and location labels (i.e., "Frog Hollow State Park" and "Mill Creek Mall"). They carried out four water tests, obtaining correct results for pH, oxygen, nitrate, and salinity. They recorded these on Poster 2, which became their data table (Figure 7). The teacher asked them to divide their poster into four quadrants, one for each water test. The students were then provided with strips of paper cut from the land use handout (LaMotte, 2000, p. 61). These described the causes for the water test results. The students were to tape these onto the poster and circle the possible causes for either an increase or a decrease. The only cause the students circled was "natural waters."

The students then received a teacher-prepared data sheet titled "Water Testing Results." At the ELMO, the teacher reviewed the process of eliminating the causes that did not relate to the Pine Creek and Muddy Run sites, but not Mill Creek. On her data sheet, Beatriz copied all possible causes listed on the poster for all tests apart from dissolved oxygen, for which she copied only two causes (Figure 8). The other three focal students did the same, contradicting the teacher's direction to relate causes to the site's water test results.

The teacher next directed the students to copy their water testing results once again. The teacher drew the format for this "chart," on a whiteboard (shown in Figure 9). Salvador and Graciela were to reproduce this information on another whiteboard while Humberto and Beatriz were to use the data to make Poster 3, shown in Figure 10. In both cases, the students copied the format as well as all possible causes, just as on the "Water Testing Results" data sheet; for example, under "salinity" they wrote, "sea water" and "tides mix salt w/ fresh water." These results did not correspond to their site, but they also wrote, "runoff from road salt," which would be the more appropriate explanation for their location.

None of the focal students linked their explanations to the Mill Creek site and instead used only the test data and the land use handout. In fact, three resources could have helped the students to make an evidence-based argument explaining their data: (1) the water quality data, (2) the land use handout, and (3) the Mill Creek handout. The teacher recorded the data for all four sites on the large

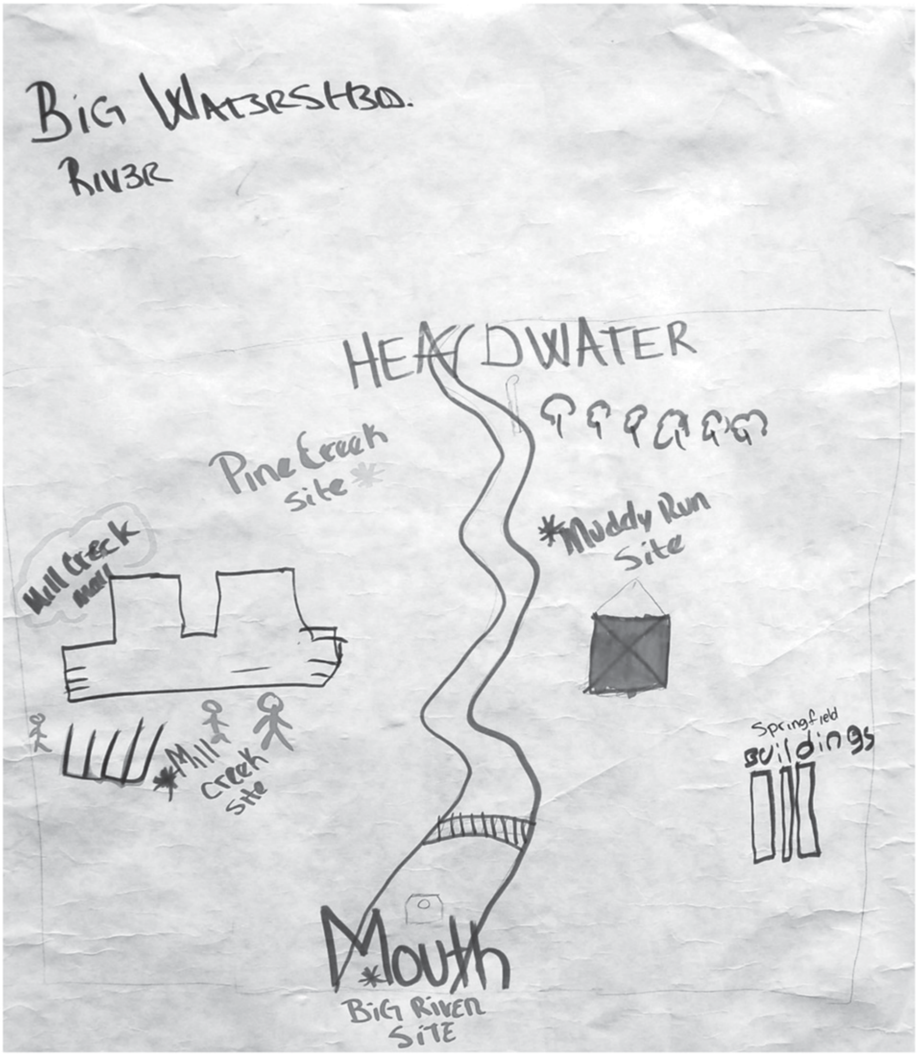


Figure 6. Poster 1.

whiteboard "chart," but accepted student responses during discussion that did not necessarily match with the site. Beatriz, for example, said that high pH was due to industrial waste, despite the fact that there was no industry at Mill Creek so the pH could not have been affected by industrial waste. In fact, the students had not used the teacher-provided "Mill Creek" resource as a conceptual model, relying instead on the land use handout. As with Poster 1, the copying approach did not create conceptual continuity with other available resources (Britsch, 2020).

As a review, the students completed the "Land Use Matching Game" (LaMotte, 2000, p. 63). This required them to match pictographs of land use practices with phrases describing the effects of land use on water quality; for example, a pictograph labeled "sewage treatment plant" would be linked to the words "Decrease Oxygen" and "Increase Nitrogen." The pictographs were to be matched to water quality verb phrases: "Increase Oxygen, Decrease Oxygen, Increase pH, Increase Nitrogen, Increase Salinity, Decrease Temperature," and "Increase Temperature." On the back, the teacher had photocopied "How Land Use Effects Water Chemistry" (LaMotte, 2000, p. 61). The students were encouraged to use this if they had forgotten any of the causes. This activity promoted thinking about the causes in a generic way, unrelated to specific sites and it reinforced the concepts developed during the water testing and poster construction activities.

Poster 4: Conceptualizing a Watershed

As a capstone activity, the students were to create final posters to visually represent their understandings about watersheds. Graciela worked with Beatriz and Salvador with Humberto. The teacher provided each pair of students with a large sheet of butcher paper and markers, again giving instructions that referenced the photocopied images in the "Big River Watershed" handout. During these instructions, the teacher looked and pointed at an enlargement of this diagram on the whiteboard and told the students to "…draw a river with some tributaries just like we have up here." Although these directions invited the students to visually communicate their understandings, the phrase "just like we have up here" also cued the copying strategy they had previously implemented. Realizing that everyone had begun copying the "Big River Watershed" handout, the teacher added directions:

> You're not drawing this watershed [points to white board]…It can be ANY watershed. This is—pretend you own a piece of land that has a river on it, okay? This is your watershed. You and your partner own this piece of land. I want you to just draw this river in the land, okay? Draw your river.

Although this addressed the copying strategy, the students continued to rely on the photocopied line drawing as a visual source for their posters instead of their own ideas. The teacher then referred the students to the photocopied written language from the list of ways in which land use affects water chemistry, previously used for Poster 2. None of the focal students used the data from Poster 2, however, or the data from their stream table observations. Instead, both pairs of students reproduced—not a complete copy—but a number of the elements taken directly from the handouts about the "Big River Watershed." Beatriz, for example, drafted three pictographs

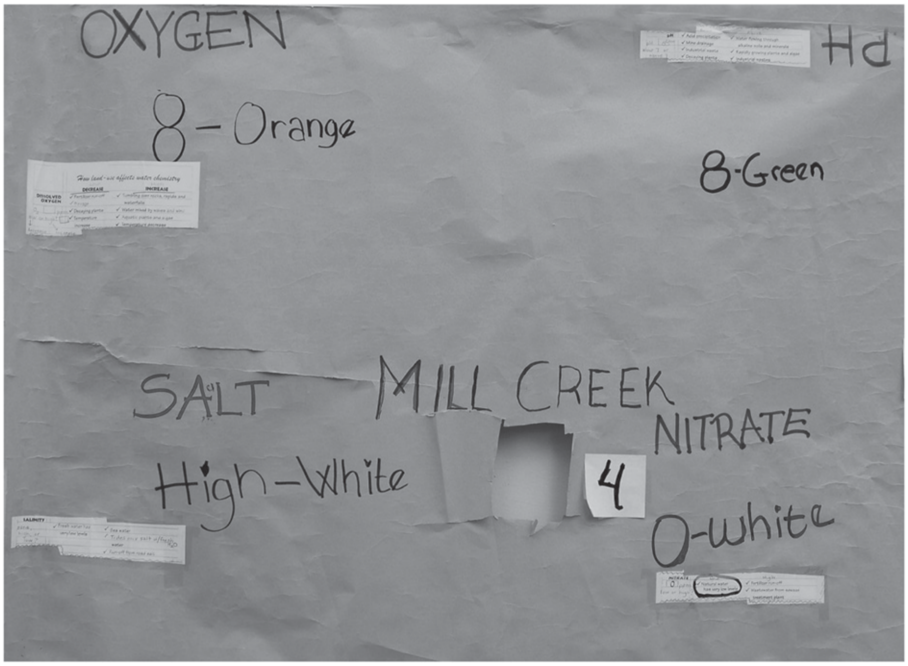


Figure 7. Poster 2.

at the top and bottom of the frame and partitioned this space with a pictograph labeled "Big River," as shown in Figure 11. These images designated particular land use practices while the written language indicated the effect of each. Essentially, all of these pictograph clusters reproduced the land use practices shown on the "Big River Watershed" handout. Beatriz added blue shapes emerging from the bottom of each factory and leading to the river in the industrial pictograph cluster. Graciela added the texture and darker color of these shapes to indicate the path of pollutants discharging into the river from each factory.

Beatriz did use the "Land Use Matching Game" (LaMotte, 2000, p. 63) as a model to visually designate the causes and the written language from handout on factors that affect water chemistry to designate the effects. She copied verb phrases such as "Increase Nitrate" or "Sewage → Decrease the oxygen" but added original written language only to label the stores in the mall pictograph cluster and to write a conclusion: "Almos [sic] the Water is Polluted." Thus, it was the visual language that drove the girls' poster production, with written language labeling this.

Humberto and Salvador, too, replicated the pictographs for the mall, farm, and forest environments from the "Big River" handout on Poster 4, using these to designate distinct land use practices (Figure 12). Their written language explained the impact on the river. Unlike the girls, however, the boys cut out photocopied pictographs that the teacher had distributed and pasted these into one of their clusters; for Muddy Run, they included a barn, cows, crops, and a photocopied cow. An angled line indicated "run-off" to the river. These land use practices directly duplicated the photocopied diagram. Humberto, however, added written explanation to elaborate the effects of these practices by combining noun phrases from the handout titled "How land-use effects water chemistry" with verb phrases from the "Land Use Matching Game." This resulted in sentence-level syntax that iterated the cause-effect relationships for each site. Although the boys did not use the term "pollution" to describe the impact on water quality, they did depict the transport of waste by drawing a series of brown lines through the blue river.

> Because of fertilizer run-off it decreases the oxygen for the fish.
> The sewage also decreases the oxygen and makes it hard for fish to live.
> Fertilizer run-off will also increase the nitrate too.

Conclusion

Our study traces the use of teacher provided resources by ELs to communicate and represent meaning in a science activity, primarily via visual and written language. Visual imagery is central to English language learning (Britsch, 2009). In fact, Barry has discussed the perceptual power of the image, noting its "ability to dominate the written or spoken word when they appear together" (1997, p. 78). Thus, concepts derive from "perceptual images" while "words and sentences are only a set of references to facts that must be given and handled in some other medium" (Arnheim, 1980, p. 493). In line with Villanueva's (2016) findings, when the focal students engaged in direct experience with the stream tables, they visually represented their observations in original ways, but when complete visual representations were already provided, the students relied heavily on duplicating both the visual and written content to create their products. This suggests the need for a distinction between "copying-as-reference" (e.g., referencing a key vocabulary list to complete a data table) and "copying-as-content" (e.g., copying as the science activity itself) (Britsch, 2020, p. 340). Both in terms of teacher practice and in terms of student response, the social semiotics of the watershed unit, however, emphasized the direct use of photocopied source material. Instruction then encouraged students to selectively borrow visual and written content, primarily from three sources, to create their products. Although the posters did offer the students a space for visual representation, this approach did not engage them in visual thinking (Seels, 1994). The result was not a synthesis of information that could be transferred to other contexts or applied to new and original construction.

Our study also expands on the work of Márquez et al. (2006) by including written

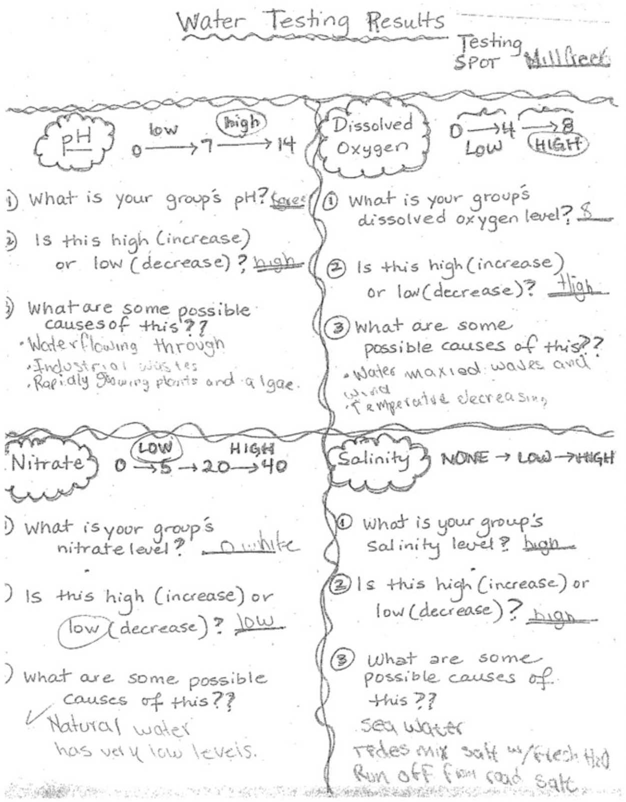


Figure 8. Beatriz's Water-Testing Results Data Sheet.

Test	Results	High/Low	Mean?
PH	4	low	• Acid rain • Mine drainage • Decaying plants • Industrial waste
Dissolved Oxygen	0	low	• Fertilizer run-off • Sewage
Nitrate	0	low	• Natural water • Very low levels
Salinity	high	high	• Tides mix salt w/ fresh water • Run-off from road salt

Figure 9. Whiteboard Chart of Water-Testing Results.

language as used by students in the science discourse. Nonetheless, although the students made use of key vocabulary words and phrases, they did so simply by relying upon sources from which to copy or delete elements. This omitted opportunities for student-generated language practice in summarizing concepts or restating objectives (Dutro & Helman, 2012). Such "deep knowledge" is essential to multimodal science instruction so that ELs are able to "name, define, explain and make use of the crucial 'big ideas' or central concepts of a topic or of the discipline" (Gibbons, 2009, p. 14). Like Villanueva (2016), we found that the focal ELs struggled to engage in higher order writing and often copied abbreviated text from teacher resources. On the other hand, we found that—as implemented— neither the students' drawings nor the presence of multimodal modes of representation necessarily helped them progress to higher language functions in their writing. Effective multimodal instruction links science materials and visual information to vocabulary and language functions that are integral to guided inquiry (e.g., synthesis, analysis, evaluation) (Klentschy, 2010). We argue, then, for an approach to sheltered science instruction in which "communication is inevitably multimodal" (Kress et al., 2001, p.6). In such an environment, learning depends not only upon the teacher's selection of modes but also upon a realistic assessment of the potential contribution of visual and written materials to ELs' ability to go on—to use the understandings developed from those materials in new and novel contexts.

Resources for use must, however, be balanced with direct instruction. Clearly, students cannot directly discover the watershed concept. Mediational resources are needed to help them make sense of the concept, but these resources must build on understandings from prior contexts as well. For example, to enlist the stream table and water-testing activities in later problem-solving tasks, students might be provided with visual and verbal information about a local watershed and a problem that is currently relevant to that watershed (e.g., water quality or flooding). Their goal is to create an artefact (e.g., poster, video, sculptural item) that (a) identifies possible causes, (b) eliminates irrelevant causes and (c) proposes a possible solution. Such an approach would allow developing writers like Humberto and Beatriz to apply the language specific to the topic to problem resolution through both visual and written language. Entering writers like Graciela can build from everyday language to the use of general, but content-related, language (WIDA, 2007) on both the word and sentence levels.

Differentiation of instruction to accommodate all ELP levels in a science classroom requires neither the simplification

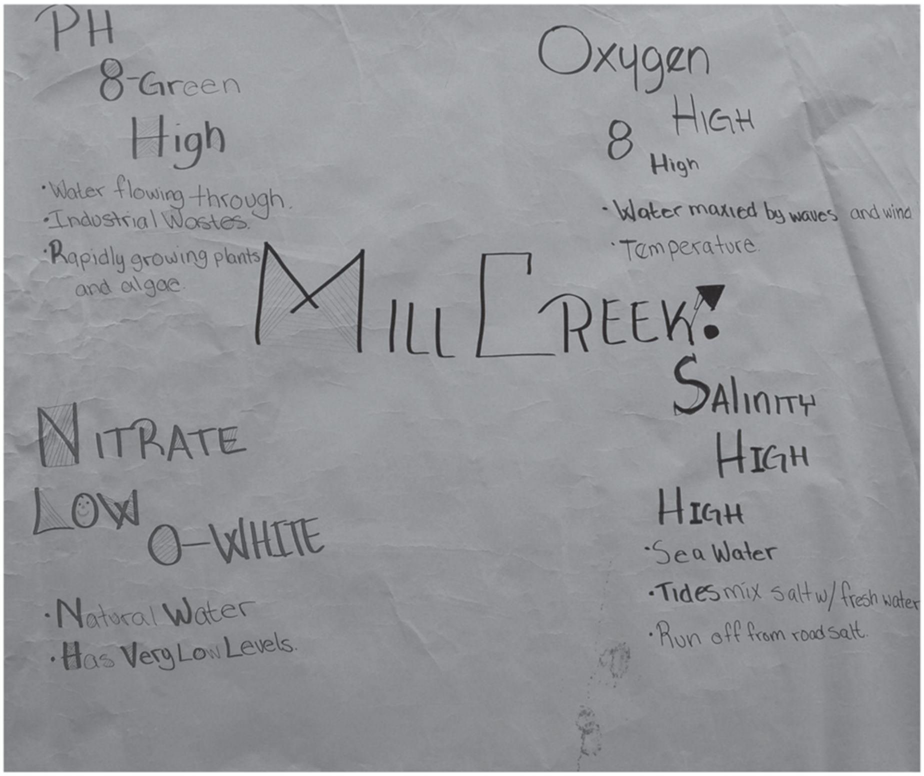


Figure 10. Poster 3.

Figure 11. Poster 4, drawn by Beatriz and Graciela.

of tasks nor the omission of higher-level thinking. Instead, it incorporates multiple modes into the design of tasks that invite more than recall and recitation in terms of thinking level and language function. In this way, visual and written engagement build and support conceptual understanding through application that is relevant to the discipline itself (Lee et al., 2013). The use of posters as a sheltered science learning task thus requires further study. Poster construction may work as a bridging activity to help students link visualization with verbal expression, but this must be coupled with the use of teacher-provided resources for questioning, application, and explanation. Even when the students' own ideas are evident in their responses (as for the stream table activity), understanding must be explicitly scaffolded, based on student engagement with the source materials. Our findings thus suggest the need for further research into the design and use of teacher-provided resources as support for the development of written and visual language by adolescent EL science learners, in particular.

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Figure 12. Poster 4, drawn by Humberto and Salvador.

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