Concept Mapping Revisited: Nurturing Children's Writing Skills in Science

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ABSTRACT
Concept mapping has long been used an assessment tool by educators to illustrate students' conceptual development of a topic over time. In this article, we chronicle the use of concept maps in a language arts environment. Focusing on a literacy tutoring program for struggling readers/writers centered on hands-on science experiments, we explain how concept maps were used as tools to engage students in authentic writing. Using the example of one struggling reader/writer, step-by-step instructions are provided used by the student's literacy tutor to transform ideas captured on a concept map (generated from experiments and readings about magnets) into a student-written non-fiction, informational book. Results from the student's pre- and post-writing assessments not only show increased writing abilities, but also mastery of science language demands.

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Introduction

For decades, concept mapping has been used as an authentic assessment strategy in education to visually represent relationships among concepts. In science education, it has been used not only to illustrate students' thinking about science concepts, but also to demonstrate how conceptual understanding develops over time and is modified as a result of instruction. David Ausubel (1968) was a pioneer in developing the concept mapping strategy and researching "structural knowledge." Joseph Novak (1977) continued with novel research in this area focusing on "meaningful learning" and using concept mapping as a metacognitive tool in science. Since their groundbreaking work, concept mapping has become a popular and effective assessment tool in K-12 classrooms (Novak, 1991).

As part of a graduate course focused on the remediation of literacy difficulties, hands-on activities related to the concept of "magnetism" was used to help motivate children's reading of non-fiction science trade books, as well as writing about their experiences. For a period of twelve (12) weeks, graduate students (tutors) worked one-on-one with struggling readers/writers (tutees) in grades 2-5. At the beginning of each session (which lasted for approximately 1 hour and 45 minutes), the graduate tutors, with the assistance of a literacy professor and a science educator, facilitated hands-on collaborative science activities about magnetism inspired by the "Gravity & Magnetism" module in the *Seeds of Science/Roots of Reading* curriculum (Lawrence Hall of Science, 2009).

As instructors of the class, we incorporated the concept mapping technique as an embedded authentic assessment instrument, which is how concept maps are commonly used in K-12 science classrooms especially when focused on big ideas (Olsen, 2008). Concept mapping was, therefore, used throughout the course to assist the children in keeping a visual record of their learning about magnets. Specifically, each child and graduate tutor was given a large piece of butcher block paper which was taped to one of the classroom walls (Note: this could also be accomplished using sticky notes which would allow the students to easily move their words around). Toward the end of each session, the children added new ideas onto their concept maps based on their hands-on experiences with magnets, as well as reading about magnets.

For one 5th grade student (pseudonym Bella), who was reading at a 3rd grade level and displayed moderate writing difficulties, concept mapping became much more than a way for her to document and demonstrate her learning about concepts related to magnetism. Concept mapping became a critical tool which assisted her in the development of her writing skills and served as a motivator to write about her experiences. In this article, we document the steps which led to Bella's increased writing ability using the concept mapping-writing technique which covers a range of Common Core State Standards in reading and writing (See Appendix A). [It is important to note that a new form of concept mapping, known as "Thinking Maps," has recently emerged which helps to organize the learner's thoughts into separate maps that build on each other in the conceptual understanding of a topic. Although current research indicates student gains in critical and independent thinking using this new mapping approach, we chose to use utilize the traditional, more basic concept mapping technique primarily because this was the children's first exposure to concept mapping of any kind (Long & Carlson, 2011).]

Step One – Brainstorming and Creating a Basic Concept Map

The graduate tutor (Jen) and Bella brainstormed words (sub-concepts) that related to the big idea of magnets. First, they had a race to write as many magnet-related words as they could and then they shared their words. Bella came up with six (6) words independently: poles, north, south, attract, repel, and magnetic. By asking Bella what words came to mind when she thought about science, she came up with three (3) more: evidence, prediction, and investigations. These words became the foundation for a basic concept map about magnets which represented Bella's prior knowledge. Once the initial concept map was created (which required some initial instruction in concept mapping rules including linking words, linking lines, and directional arrows), the words were added to their science vocabulary inventory.

Step Two – Adding New Ideas and Making Connections

Bella added new words to her vocabulary inventory after the first hands-on activity using force blocks, springs, and rubber bands (Note: A science notebook page was used during each activity not only to help guide the exploration, but also to nurture writing as scientists; see Appendix B for a sample notebook page). Specifically, Jen asked, "What new things did we learn today" and "How can we add them to our map?" Jen tried to focus on the specific science language demands used during the hands-on activities. Reading excerpts from the non-fiction trade books, *Forces* and *What My Sister Taught Me about Magnets*, also assisted Bella in her understanding of the science concepts related to the force of magnetism. It is important to note that Bella was not simply scanning or browsing these science trade books, but rather she was employing a core "Science and Engineering Practice" as identified in the *Next Generation Science Standards* (*NGSS*): "obtaining, communicating, and evaluating information" (practice 8) (See Appendix A for *NGSS* connections). In other words, Jen assisted Bella in reading the non-fiction science texts "to extract information accurately." As stated in *A Framework for K-12 Science Education*, "Because the precise meaning of each word or clause may be important, such texts require a mode of reading that is quite different from reading a novel or even a newspaper" (NRC, 2012, p. 74). Bella would use this practice whenever she used the trade books, as well in the creation of her own non-fiction trade book.

While adding these new words to the map, Jen emphasized the use of linking words to make sentences (propositions) about magnets that she knew to be true. Jen explained that they would continue to work together on their concept map throughout the semester, adding new concepts and vocabulary words after experiencing new ideas during the hands-on activities. Jen conveyed to us early in the semester that she planned on using the concept map with Bella as an informational text. In other words, Jen intended to use key elements of concept mapping combined with Bella's concept map as a literacy strategy, which we refer to as the "concept mapping-writing strategy." (Note: Bella's concept map was written in pencil, so the same piece of butcher block paper was used throughout the semester. After each new learning experience, once Bella realized that a proposition was inappropriate or scientifically incorrect, she erased or modified the proposition.)

Step Three – Reading the Concept Map

At the next session, the graduate tutors and tutees participated in a hands-on activity using magnets and iron filings to illustrate magnetic lines of force. Afterwards, when they revisited the concept map, Jen reported that Bella was dissatisfied with the sentences she created on the map due to her limited vocabulary of linking words. Initially, Bella used "is" as her only linking word impeding her ability to fully express her level of understanding. With moderate scaffolding, Bella began using a variety of linking words once she realized that she could use short phrases to make the connections. An example of scaffolding that was consistently used by Jen was reading a proposition aloud and asking Bella if it made sense to her or if she wanted to modify the proposition in any way. This type of conversation served as a check-for-understanding for Bella which, in turn, allowed her to refine her original propositions. Bella really enjoyed reading the map as sentences. Jen and Bella discussed the possibility of using the concept map as the basis for creating and publishing a non-fiction book titled, "All about Magnets." Bella loved the idea! She would use the information on the concept map to write full sentences, and then use those sentences to create her writing piece.

As identified in the "Science and Engineering Practices" of the *NGSS*, Bella employed two fundamental practices while developing her concept map: "Asking Questions" (practice 1) and "Developing and Using Models" (practice 2). In essence, the concept map served as a visual model or representation of Bella's "structural knowledge" of the concept of magnetism. Her visual model was continually revisited and revised over the course of the twelve weeks illustrating her increased content knowledge. At the same time, Bella was "asking questions" about magnets as she critiqued the accuracy and completeness of her concept map propositions. Because of the strong visual aspect of this process, this strategy is particularly effective for teaching English Language Learners (ELLs). According to Carr, Sexton & Lagunoff (2006), using a visual approach such as concept mapping, educators can effectively assist ELLs with the language demands of science without "watering down" the science content.

Step Four – Writing Sentence Cards

One day per week over the next several weeks, we continued to facilitate hands-on activities related to magnets including: magnetic attraction between magnets and objects containing iron, the Law of Magnetic Poles, the strength of magnets and their shapes, the interaction between a magnet and a compass, and Earth's magnetic field (See Appendix C for more detailed information about each of the science activities implemented). With each session, Bella continued making new connections on the concept map using linking words/phrases. After the final words were added to the concept map (over 18 in all), Bella began her writing project (See Figure 1 for Bella's completed concept map). Bella used the concept map to create meaningful sentences about what she had learned about magnets. Using pieces of paper cut into halves, she wrote different sentences on each piece. For example, Bella combined the three propositions: "Magnets *have* Poles," "Poles *can be* South," and "Poles *can be* North." Her new sentence card stated, "Magnets have poles. They have a north and a south pole." Bella also created another sentence card focusing on the Law of Magnetic Poles (See Figure 2 for two sample sentence cards). Once again, Bella utilized a core "Science and Engineering Practice." Specifically, in writing her sentence cards, Bella was "constructing explanations" (practice 6) which reflected her understanding of key principles related to magnetism. Using evidence that she gathered from the hands-on activities (practice 3) and which were recorded on her concept map, she was able to construct explanations and explain her thinking on the sentence cards.

Figure 1. Bella's completed concept map

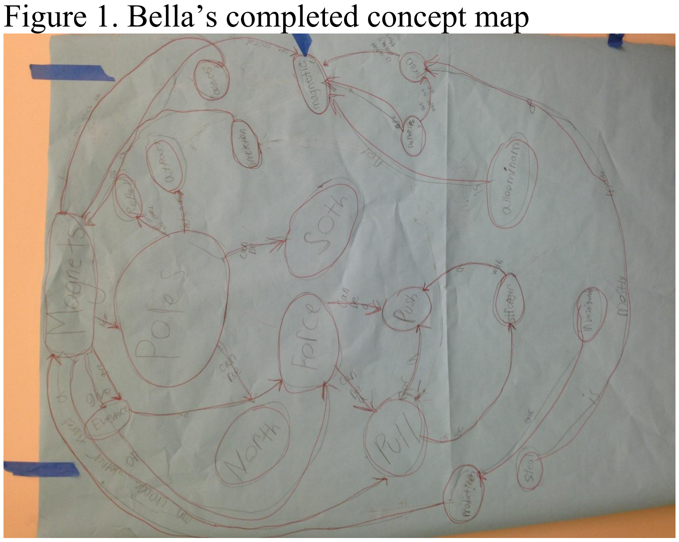
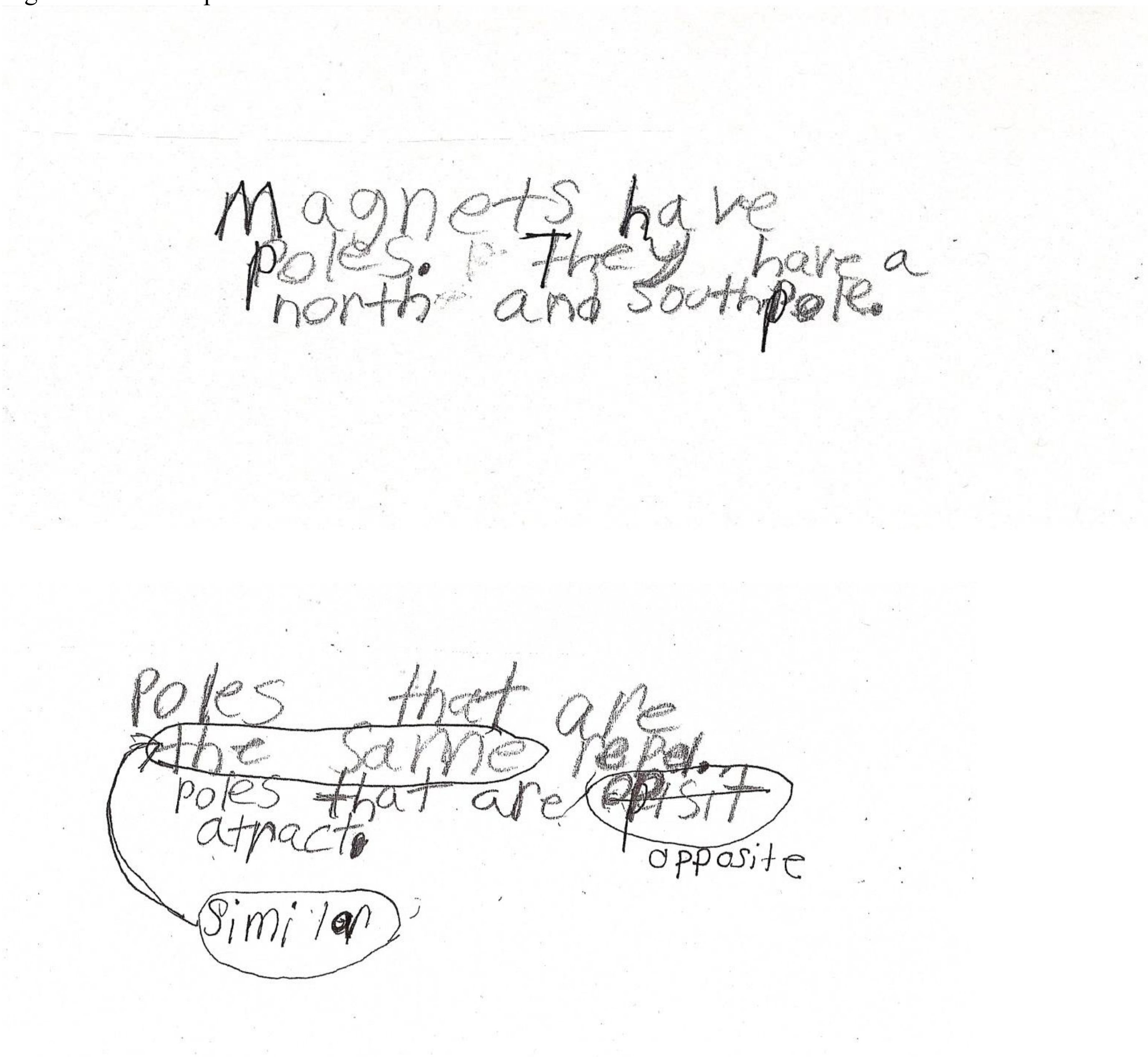


Figure 2. Two sample sentence cards



Step Five – Organizing Sentence Cards

After Bella completed writing all of her sentence cards (thirteen in all), she immediately began to organize the pieces of paper. Unprompted, Bella began placing the sentence cards into piles or groups that seemed to fit together. Jen knew that each group of cards would become the content for each chapter in her book, but at that moment Bella simply needed to organize the cards because there were so many of them. According to H. Taba and her colleagues' work on the Inductive Model of Concept Development (1971), an individual can obtain a deeper or fuller understanding of a concept once his/her ideas are "organized" through the process of "grouping and labeling." Interestingly, this process came naturally for Bella.

Procedurally, Jen read the sentence cards one by one, and Bella decided which sentence was the best match to another sentence card. She put the matches into different piles based on how well they went together. Sometimes Jen asked Bella guiding questions such as "Why do you think that card goes there?" to be sure that she was making logical choices in her sorting. At times, Bella felt that it was necessary to add supporting sentences when she felt something was missing. Then within the piles, Bella placed the sentence cards in sequential order which made sense to her. After all the cards were grouped and paper-clipped together, they worked together to assign each group a general category label that captured the main idea of the sentences in that pile (Taba et. al., 1971). The following group labels became the chapter titles for the trade book: Magnetic or Not; Iron and Magnetism; Poles (North and South); Force; and Pushes and Pulls (Note: we suggest using index cards, instead of pieces of paper, to help facilitate grouping the sentences).

Step Six – Editing Sentence Cards and Creating a Trade Book

Before Bella started typing her book, Jen assisted Bella with editing the sentence cards focusing particularly on spelling, proper conventions, mechanics, and word choice. After the editing process was complete, Bella typed each pile of sentence cards onto a separate page in a word processing document, added illustrations (with the help of a search engine), and included nonfiction text features such as a table of contents, section headings, captions for illustrations, and bold-face vocabulary words. The previously mentioned science trade books served as "mentor texts" or "model texts" in this process. Finally, the pages were bound together, along with a title page, to create the nonfiction trade book. Bella's book was presented as part of a literacy center open house at the end of the semester. It was clear that Bella was proud of her work, and Jen was equally pleased.

Results

Bella's writing skills were evaluated using the "6 +1 Trait Writing Model of Assessment" developed by Educational Northwest (2011). This assessment instrument is used to rate students' writing samples on a scale of 1-5 on several aspects of writing (see Table 1).

Score	Interpretation
1	Writer does not show any strength in area being tested.
2	Writer is emerging in area being tested.
3	Writer is developing in area being tested.
4	Writer is effective ("strengths outweigh the weaknesses") in area being tested.
5	Writer is strong (demonstrates "control and skill") in area being tested.

Table 1. Interpretation of "6 +1 Trait Writing Model of Assessment" scores

To create a baseline of Bella's writing ability at the beginning of the semester, she was asked to write a three-paragraph story about a topic of interest. Scores on the 6+1 Trait Writing Assessment for this initial writing sample were used by her tutor to determine three areas of focus for writing instruction: organization, word choice, and sentence fluency. Bella's final writing piece for the semester was used as a post-assessment for these traits. While the two writing tasks were different, it was important to determine what Bella could do independently and then provide scaffolding through the use of the concept mapping-writing strategy to improve her writing abilities (See Table 2).

Area Being Tested	Pre-Tutoring Score (Independent – Baseline Writing Sample)	Post-Tutoring Score (With Scaffolding – Final Writing Project)
Ideas	4	4
Organization	3	4*
Voice	3	3
Word Choice	3	4*
Sentence Fluency	2	4*
Conventions	2	2

Table 2. Bella's "6 +1 Trait Writing Model of Assessment" pre- and post-tutoring scores (Note: asterisks indicate areas of improvement)

Prior to tutoring, Bella scored "developing (3)" in the area of *organization*. Although she wrote in a logical sequence, she relied heavily on sequencing words (such as "next" and "then") when transitioning, focused on non-essential details, and rushed through important parts of her story. After using the concept mapping-writing strategy, Bella's post writing assessment scored "effective (4)" in this area. The concept mapping-writing experiences helped her not only with organizing (grouping and labeling) her sentence cards, but also transforming the cards into her own non-fiction trade book organized by chapter. Overall, the concept mapping technique greatly assisted Bella in shaping and organizing her thoughts, and this was reflected in her final writing project.

Bella was initially unable to effectively capture the reader's attention with her *word choice* and scored "developing (3)" in this area of her pre-tutoring writing sample. Her story consisted solely of everyday nouns and mundane verbs. For example, she stated what happened with little or no elaboration (e.g. "I hit the ball"). After using the concept mapping-writing strategy, she scored "effective (4)" in this area. We attribute the growth in this trait from repeatedly adding to and extracting words from her concept map. In essence, her concept map served as a working inventory of ideas for her to draw upon when writing.

Lastly, Bella was initially rated "emerging (2)" in the area *of sentence fluency*. Many sentences began the same way; she started many sentences with "I" or with a sequencing word; however, her final writing project was assessed as "effective (4)" in this area. This was her greatest area of growth which we attribute to experiences with combining and refining propositions from the concept map into meaningful sentences. As Jen stated, "Bella learned to construct sentences in many different ways, which in turn gave her writing better rhythm and flow."

With regard to science language demands, we also implemented a "Science Vocabulary Knowledge Rating Scale" based on ten (10) key vocabulary words inspired by the *Seeds of Science/Roots of Reading* magnetism module (See Appendix D). We considered what science words related to magnetism, as well as words related to the nature of science, which the students would need to understand to successfully complete the activities and readings over the course of the semester. Vocabulary or knowledge rating is a formative assessment strategy designed to assess students' background knowledge of a concept. The use of this type of rating scale can help students become aware of new vocabulary terms and can activate students' prior knowledge (Young, Righeimer & Montbriand, 2002). Students are first asked to rate their own understanding of each vocabulary word using the rating scale. If they state that they know the word well, then they are asked to give a definition or "showing sentence," which is a sentence that illustrates a student's understanding of the word's meaning (Caplan & Keech, 1980). At the end of the unit, the words are revisited on the rating scale. Comparing the students' self-ratings and the development of their sentences or definitions can be used to show growth. If the student gives a definition or develops an appropriate showing sentence at the end of the unit, then that term can be considered to have been mastered (Young, Righeimer & Montbriand, 2002).

All students were asked to complete the Science Vocabulary Knowledge Rating Scale at the beginning of the semester and at the end of the semester. Bella showed significant growth in her science vocabulary knowledge. At the beginning of the semester, Bella was "proficient" in only three (3) out of ten words (10). In other words, she could either define or use the following words in a "showing sentence": scientist, prediction, and evidence. She claimed seeing many of the other magnet-related words, but could not provide a definition or showing sentence to explain what they meant. By the end of the semester, Bella was "proficient" in *all* of the vocabulary terms. For example, whereas Bella could not define or use the word "attract" in a showing sentence at the beginning of the semester, by the end of the semester she conveyed to Jen, "When two magnets come together that's called 'attract.'" Bella's valid showing sentences for all of the key vocabulary words were a strong indicator of her mastery of the concepts related to magnetism.

Conclusion

Research has shown that "science makes kids *want to read*" (Lundstrom, 2004). We whole-heartedly agree; however, according to our experiences, we found that concept mapping in science makes children *want to write*. Although this article tracks the literacy development of one 5th grade child which resulted in increased writing skills in the areas of organization, word choice, and sentence fluency, this concept mapping-writing strategy is now being used with many of the struggling readers/writers who participate in our graduate remediation course. In addition to creating non-fiction texts as Bella did, tutees have since created poetry, graphic novels, narrative fiction, how-to texts, and informational brochures by incorporating science information from their concept maps. Based on preliminary findings, the majority of children participating in our remediation program have shown similar increases in their writing abilities.

The approach described in this article can be easily modified for classroom use. First, the teacher would model the concept mapping-writing strategy for the entire class. Then, the students would utilize the strategy in small, cooperative groups. Specifically, after the students conduct a series of activities on a particular science topic, they would collaboratively add their new learning onto a group concept map, co-develop sentence strips based on their concept map, and then write a non-fiction trade book together as a group. Once this has been practiced using a cooperative group approach, students would be responsible for their own writing using individual concept maps and sentence cards focused on another topic in the science curriculum; therefore, through a gradual release of responsibility, the classroom teacher would be able to use the concept mapping-writing technique as an individual form of assessment. Although further research on the efficacy of this strategy is necessary, we invite you to implement the concept mapping-writing technique in your own science classroom.

Concept Mapping Resources

http://go.hrw.com/resources/go_sc/gen/HSTPR006.PDF

http://www.readingrockets.org/strategies/concept_maps

References

Ausubel, D. P. (1968). *Educational psychology: A cognitive view*. New York: Holt, Rinehart and Winston.

Caplan, R. & Keech, C. (1980). *Showing writing: A training program to help students be specific*. Berkeley: Bay Area Writing Project, University of California.

Carr, J., Sexton , U. & Lagunoff, R. (2006). *Making science accessible to English learners: A guidebook for teachers*. San Francisco, CA: WestEd.

Educational Northwest. (2011). 6+1 Trait Writing Model of Assessment. Retrieved from: http://educationnorthwest.org/resource/464.

Lawrence Hall of Science. (2009). *Seeds of science/Roots of reading*. Washington, D.C. Delta Education.

Long, D. & Carlson, D. (2011). Mind the map: How thinking maps affect student achievement. *Networks: An Online Journal for Teacher Research, 13*(2), 1-7.

Lundstrom, M. (2004). Media-savvy kids. *Instructor, 114*(4), 16-21.

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). Common Core State Standards for English language arts and literacy in history/social studies, science, and technical subjects. Washington, DC: Authors.

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press.

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

Novak, J. D. (1977). *A Theory of Education*. Ithaca, NY: Cornell University Press.

Novak, J. D. (1991). Clarify with concept maps. *The Science Teacher, 58*(7):45-49.

Olson, J. (2008). Concept-focused teaching: Using big ideas to guide instruction in science. *Science and Children, 46*(4), 45-49.

Righeimer, J. M., & Montbriand, C. (2002). *Strategic teaching and reading project: Comprehension resource handbook*. Naperville, IL: North Central.

Taba, H., Durkin, M. C., Fraenkel, J. R., & NcNaughton, A. H. (1971). *A teacher's handbook to elementary social studies: An inductive approach* (2nd ed.). Reading, MA: Addison-Wesley.

Appendix A
Connections to the *Common Core State Standards* (CCSS) in ELA-Literacy & the *Next Generation Science Standards* (NGSS)

I. Common Core State Standards Connections: ELA-Literacy

W.3.2

Write Informative/explanatory texts to examine a topic and convey ideas and information clearly.

W.3.4

With guidance and support from adults, produce writing in which the development and organization are appropriate to task and purpose.

W.3.5

With guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, and editing.

W.3.6

With guidance and support from adults, use technology to produce and publish writing.

W.3.8

Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence into provided categories.

RI.3.1

Ask and answer questions to demonstrate understanding of a text, referring explicitly to the text as the basis for the answers.

II. NGSS Connections

3-PS2 Motion and Stability: Forces and Interactions
PS2.B: Types of Interactions
Electric and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (3-PS2-3), (3-PS2-4)

Cross-Cutting Concept – *Cause and Effect***:**

Cause and effect relationships are routinely identified.

Science and Engineering Practices:

*Practice 1: *Asking Questions and Defining Problems*
Asking questions and defining problems in grades 3–5 builds on grades K–2 experiences and progresses to specifying qualitative relationships (Students ask questions that can be investigated based on patterns such as cause and effect relationships).

Practice 2: *Developing and Using Models*
Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.

*Practice 3: *Planning and Carrying Out Investigations*
Planning and carrying out investigations to answer questions or test solutions to problems in 3–5 builds on K–2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.

Practice 6: *Constructing Explanations and Designing Solutions*
Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.

Practice 8: Obtaining, Evaluating and Communicating Information
Obtaining, evaluating, and communicating information in 3–5 builds on K–2 experiences and progresses to evaluating the merit and accuracy of ideas and methods. (Students obtain and combine information from books and other reliable media to explain phenomena.)

***NOTE**: Although Practice 1 and Practice 3 directly relate to standard **3-PS2** "Motion and Stability: Forces and Interactions" in the *Next Generation Science Standards* (NGSS), Practices 2, 6, and 8 were also essential skills used during the concept mapping-writing experience.

Appendix B
Sample science notebook page

Name: _______________________________ Date: ____________________

Magnetic Poles

All magnets have a *North Pole* and a *South Pole*. What happens when you bring the poles of different magnets together? Draw and label what you observed during the activity:

Key words: North pole (N), South pole (S), attract, repel, like poles, opposite poles, Law of Magnetic Poles

What happens when you bring like poles together? What happens when you bring different (opposite) poles together?

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If a magnet's poles are not labeled (N and S), what can you do to figure out where the poles are? ____

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Appendix C. Summary of science activities and big ideas related to magnetism

Big Science Ideas	Science Activities
• A force is a push or a pull between to objects. • Some forces can act when two objects are touching (contact). Other forces can work without touching (non-contact).	**Student Investigation:** Making Forces with Force Blocks **Materials:** force blocks, springs, rubber bands **Summary:** Using force blocks, springs, and rubber bands, students investigated forces. When pushing two force blocks together connected with a spring in the middle, students experienced the spring "push" the blocks apart. When pulling two force blocks apart with a rubber band connected in the middle, students experienced the rubber band "pull" the blocks together.
• Forces can work without touching (non-contact). One example is the force of magnetism. • Magnetic Lines of Force represent the pathways of the push or the pull. This is also called a Magnetic Field.	**Student Investigation:** Making a Magnetic Field *Visible* **Materials:** Paper clips, string, magnets, masking tape, metal shavings, printer paper, trays **Summary:** In the first part of this activity, one end of a string was taped to the table and the other end was securely fastened to a small paper clip. Students attracted the paper clip with the magnet without allowing the magnet to touch the paper clip; the paper clip was suspended in the air. In the second part of the activity, we covered a bar magnet (on a tray) with a piece of white paper. Iron filings were then sprinkled onto the paper. The iron filings revealed the shape of the Magnetic Field.
• Magnets do not attract non-metals. • Magnets will attract some metals (iron) but not others. • All magnets have the ability to attract other magnets.	**Student Investigation:** What do magnets attract? **Materials:** magnets, bag of assorted objects to test (aluminum foil, nails, plastic spoons, pennies, paper clips, etc.) **Summary:** Students explored different objects to determine which ones were attracted to a magnet and which ones were not.
• Magnets can have different shapes. • Different magnets have different strengths.	**Student Investigation:** Strength of Magnets **Materials:** magnets, paperclips, rulers **Summary:** A paperclip was placed on a table and a ruler was placed vertically next to the paper clip. Students slowly lowered a magnet down the ruler. When the magnet attracted the paper clip, the distance between the magnet and the paper clip was recorded. This was done for different types of magnets (horseshoe, bar, button, ring magnets) to determine that different magnets have different strengths.
• All magnets have a north pole and a south pole. • Different (opposite) poles attract each other, but like poles repel each other.	**Student Investigation:** The Law of Magnetic Poles **Materials:** assorted magnets **Summary:** Students explored what happens when two like poles come near each other and when two opposite poles come near each other.
• Many everyday objects contain iron which makes them magnetic. • If an object does not contain iron, it is non-magnetic.	**Student Investigation:** What everyday objects are magnetic? **Materials:** horseshoe magnets **Summary:** Students conducted a building scavenger hunt to find objects that are attracted to a magnet.

• A compass contains a small, lightweight magnet. • The Earth is like a magnet. It has a north magnetic pole and south magnetic pole. • One end of a compass needle will always point toward Earth's North geographic pole (which corresponds to its south magnetic pole).	**Student Investigation:** What happens when you bring a magnet near a compass? Simulating Earth's magnetic field by making an "Earth Ball" **Materials:** compasses, bar magnets, Earth balls **Summary:** Students first explored the effect of bringing a magnet near a compass and determined which end of the compass needle was a north pole and which end was a south pole. Students also learned that one end of the compass needle always points toward Earth's North geographic pole (Note: we labeled the classroom walls as North, South, East, and West). Afterwards, students created an "Earth Ball" by inserting a powerful bar magnet inside of a soft, foam ball resembling the Earth. Students had to determine which way to orient the bar magnet inside the ball to accurately simulate Earth's magnetic field. Earth's magnetic field was then simulated by placing paper clips on the outside of the Earth Ball.

Appendix D. Science Vocabulary Knowledge Rating Scale

Vocabulary Word	***I don't know anything about the word in the context of science (i.e. haven't seen or heard the word before in the context of science).*** **Focus**	***I have heard or seen this word in the context of science (i.e. somewhat know what is means, but can't use it in a "showing sentence").*** **Emerging**	***I know this word well in the context of science (i.e. can define it* OR *use it in a valid "showing sentence").*** **Proficient**
1. Scientist			
2. Force			
3. Magnetism			
4. Attract			
5. Repel			
6. Pole			
7. Evidence			
8. Explore			
9. Investigate			
10. Prediction			