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Abstract

Preservice teachers enrolled in a science content-based course wrote stories that could help their future students understand a science concept. First, participants chose their topic and wrote the story with few guidelines to establish a baseline. In the next part, a different set of students were given a choice of three topics (based on force, electricity, and heat misconceptions), and collaborated to write stories with guidance from the instructor. Stories were analyzed for narrative and science units, and test scores examined. Without guidance, many students struggled to find ways to integrate science within a story. With guidance, participants wrote stories that included more narrative elements overall, and participants felt the stories helped them understand the concepts.

The Stories They'd Tell: Preservice Elementary Teachers Writing Stories to Demonstrate Physical Science Concepts

Preservice elementary teachers' low self-efficacy in science has been reported in many studies (e.g., Appleton, Gins, & Watters, 2000; Dillon, Oxborne, Fairbrother, & Kurina, 2000; Jarvis & Pell, 2004). When I take informal polls of the students in my science content-based courses for elementary education majors, well over half of the students typically report that they do not like, or are not good at, science. When I ask those same students which subjects they *do* like, either to learn or to teach, about two-thirds of them tell me they enjoy reading and writing (this is supported by the literature, e.g., El-Hindi, 2003; Hand & Prain, 2006).

I tend to use stories in my teaching, and research shows that other history, science, and language arts instructors use stories as a teaching method in order to relate the subject to "real life" and make students feel more comfortable in the class (Egan, 2005; Frisch & Saunders, 2008; Hadzigeorgiou, 2006; Hamer, 1999; Rex, Murnen, Hobbs, & McEachen, 2002). Stories are one way that humans organize and contextualize knowledge (Schank & Abelson, 1995) and so it makes sense to help novice learners assimilate new information by making connections using stories.

The idea that stories can and should be used to teach science is not new. In 1995, Stinner offered his ideas toward developing a "more humanistic science education" by incorporating science stories at every level of science education curriculum. Much of the work on science stories has focused on the history of science, with an emphasis on great scientists as heroic protagonists. However, as Solomon (2002) wrote, students have difficulty empathizing with these epic figures. In order to make the science story more accessible, the characters should be familiar; Solomon suggested that it is important to include both the scientist's successes *and* failures in a story, so that students can see themselves in the character. If the student can connect with the character, the story connects to his/her imagination, and thus the story becomes more meaningful and useful.

Most of the research done on using stories to learn science concentrates on science stories that have been written by scientists or writers or stories that were written by the researchers themselves. For example, Negrete (2002) examined the extent to which reading science-based stories (Primo Levi's "Nitrogen" and Dnieprov's "Crabs Take Over the Island") helped students learn science, and found that students could learn science from literary stories and found them more enjoyable than traditional textbooks, though story groups did not show evidence of learning the concepts better than did students who learned through textbooks. Ford (2004) examined how preservice teachers choose children's science literature for use in their classrooms, and found that preservice teachers looked for attractive illustrations, concise writing, and engagement of the reader, but were inattentive to accurate science content.

Rather than focusing on previously published stories, however, this study seeks to explore a new area—the preservice teachers' own stories. It can be useful to give the intended audience a voice in story creation as well. In order to acknowledge and value different individuals' cultures and perspectives, it is important to pay attention to the stories students tell and the way that they tell them (Banister & Ryan, 2001; Hulland & Munby, 1994; Ritchie, Rigano, & Duane, 2008), rather than always focusing on the stories told by an authority figure or dominant culture as in much of the research above.

Banister and Ryan (2001) told a story about the water cycle, and then gave elementary students a chance to rewrite the story using their own words and experiences. They found that this method helped students expand upon and change their own ideas. The importance of giving children a chance to tell their stories is supported by research (Mallan, 1991; Ritchie et al., 2008), because it gives children a chance to use their own voices to make sense of concepts, and allows them to feel connected to the story. Students of different cultures or learning styles often have different ways of telling their stories, and so giving each student an opportunity to use his/her own voice is a way of valuing them as people. If preservice teachers find that writing science stories helps them understand concepts, they may be more willing to help their future students write science stories in turn.

Many elementary teachers are not confident in their ability to teach science, particularly physical science, in part because they do not feel they understand the concepts themselves (e.g., Abell & Smith, 1992; Jarvis & Pell, 2004; Yager & Weld, 1999). Many elementary teachers perform well at literacy instruction (Akerson, Flick, & Lederman, 2000; El-Hindi, 2003), and feel comfortable and confident in this field. It could be useful for such a teacher to embrace the areas in which she feels strong in order to strengthen an area of perceived weakness. Based in part upon this observation, physics education researchers have called for more use of narrative to humanize the teaching in the field (Campbell, 1998; Hadzigeorgiou, 2006).

Ritchie et al. (2008) reported on their interpretive study examining the efforts of a class of fourth-grade students co-creating an "ecological mystery" with their teacher, in an effort to combine a story with science. One of the authors of the paper was also the teacher of the class, and worked with the students as "co-author, editor, teacher, and learner" (p. 150). Throughout the project, the teacher would lead brainstorming sessions with the students, guide discussions, and allow students to vote on what should happen next in their story. Students could contribute to the story in large-group, small-group, or individual writing sessions, and the teacher would make decisions about what would be included in the story based on consistency with the storyline, descriptive language, inclusion of science, clever use of dialogue, or novel plot developments. At the same time, the students were given an opportunity to practice writing in a more formalized factual genre by writing a structured report on a marine organism.

Qualitative analysis of Ritchie et al.'s (2008) project included observations, interviews, videotapes, and analysis of artifacts including drafts by students and contextual analysis of the completed story. Ritchie et al. concluded that the project kept the students engaged in the subject and gave them a chance to demonstrate written and spoken fluency with the science concepts included in the story. The authors acknowledge that the teacher for this study was particularly skilled and motivated to accomplish this project, but suggest that other teachers, even without similar experiences, motivation, or extended time periods to use for such a project, could accomplish similar goals by writing short stories with students.

In order to determine the degree to which preservice teachers could accomplish the goal of using stories to enhance science fluency in students, it is useful to establish some sort of baseline to determine where our teachers are starting out, and how far they have to go. To this end, the research questions that guided this study include:

RQ1: Without much guidance (as a baseline), what kinds of stories do preservice elementary teachers tell to demonstrate a physical science concept?

RQ2: How do preservice teachers collaborate in order to write a science story, and how does guidance and collaboration in the story-crafting process change the science stories students write?

RQ3: To what extent does the process of writing the stories show evidence of contributing to students' understanding of the concept(s)?

Methodology

Setting and Participants

The study took place in a mid-sized university in the southern United States. Preservice elementary education majors enrolled in a required integrated science content course were the target population for the study. The two integrated science content courses are required courses for elementary education majors. In order to enroll in these integrated science courses, elementary education majors must get a "C" or above in two prerequisite "introductory" science courses, both of which are taught by science faculty and focus on Environmental Science. The integrated science courses include "Physical Science," which includes the concepts force and motion, energy, heat transfer, electricity and magnetism, sound and light, simple chemistry, and the solar system. The other integrated science course is "Life and Earth Science Concepts," but was not included in this study. Instead, I focused on the "Physical Science" course, in part because the elementary education majors have informally reported that they have more difficulty with the concepts discussed in that course because they find the concepts to be less "tangible." At the time of this study, most students were only required to take one of the integrated science courses, but subsequent cohorts must take both (in any order).

Although these courses are content (not methods) courses, the students who enroll in the courses are all elementary education majors. The instructors who teach the courses are based out of Biology and Physics departments, but most of the instructors have solid backgrounds in science education as well as science, and the courses were developed with an eye to the *National Science Education Standards*. Each course includes two, one-hour and fifteen-minute lecture periods and one two-hour lab per week. Students have to pass these integrated science courses before they can begin taking methods courses and student teach, and most students in the course have the credits to be counted as sophomores or juniors.

Participants in the study were representative of enrollment in the course overall. As is typical for elementary education courses, the students in these classes were 90-95% female, depending on the semester. The age range of participants was from 18-45 years old: the course usually contained around 30% non-traditionally aged students and participants in the study reflected that ratio. Race/ethnicity distribution in the course was about 85% white, 10% African-American, and 5% Hispanic, Indian, or other ethnicity.

Elementary education majors are required to take several courses about teaching reading and writing, and at the time of the study most of the students had not yet taken these courses; most would take it the following semester. The average grade in these literacy courses in the semesters following data collection for this study was an A, which provides evidence that the target population does, in fact, show competence in teaching reading and writing.

Many times throughout the course, I used story-examples to illustrate concepts during the lecture portion of the class. I explicitly called attention to the fact that I was using a science story by beginning with a statement such as "let me tell you a story…" These stories could be based on personal experience, historical events, or completely fictional. In this way, students in the course became acquainted with what I meant by a "science story," although I never gave them written versions of these stories. As a separate project, however, students were asked to identify and describe fiction trade books that deal with a physical science concept of their choice.

Data Collection

Research question 1: Baseline stories. In first part of the study, students could volunteer to participate, and received a few extra credit points as compensation for their participation. An alternate extra-credit assignment was offered at the same time, in order to eliminate the possibility of students feeling coercion to participate. This portion of the study ("part 1") was completed during the fall semester of 2007, during which time students were only allowed to contribute one story, and the spring semester of 2008, during which time a new cohort of students could contribute up to two stories. Eight students contributed a story in the fall of 2007, and eight different students contributed stories in the spring of 2008—of this last group, six students contributed two stories, for a total of 22 stories collected.

Participants were asked to write a story that would help demonstrate a science concept of their choice to their future students (a copy of the guidelines students were given is included in Appendix A). The participants were told they could write a story that was either fictional, based on true events, or some combination of the two. Students were told that the story had to have some kind of main character (though that character need not be human), something had to happen to the main character, there should be some kind of resolution, and the science concept they chose should be a clear part of the story. In addition, students were asked to answer the following questions: (a) how does your story illustrate the concept; (b) did writing the story help increase your own understanding of the concept, and (c) could this story reinforce or create any misconceptions for the students?

Research question 2: Collaborative stories. The second part ("part 2") of the study was conducted with a new cohort of elementary education students in the fall semester of 2008, based on the results of the first part of the study. A total of 34 students participated in this part of the study, completing five stories (one story was not carried through to completion, and those data were not used for the study). There were eleven students who were enrolled in the course whose data were not included in the study.

Data from the first part of the study were used to inform this second part of the study. For this portion, all students in the course were required to contribute to one of three stories: force, electricity, or heat. Students in the course were divided into two lab sections, so there were a total of six stories (two for each concept, though as noted above, one was not used as data) being written, each by a group of 6-8 students. These topic areas were initially chosen because they were concepts frequently chosen by the students from part one. In order to provide structure to the stories, students were asked to focus their stories specifically around a misconception (guidelines that students were given are included in Appendix B). The force misconception was that if a ball is thrown, the only force acting on the ball is the force from the thrower; the electricity misconception was that there are many different ways to connect a simple electric circuit; and the heat misconception was that putting on a sweater "makes" one warmer. These misconceptions were chosen because student averages on Misconception Oriented Standards-based Assessment Resource for Teachers (MOSART) pre-test items for these ideas were relatively low for the group overall, indicating that the students themselves may have some difficulty with these misconceptions.

Students participated in co-constructing their stories via *WebCT* online discussion boards already used as a part of the course. The semester was split up into three-week "phases", and students were asked to make at least one contribution to the story at each phase. Phase one consisted of brainstorming possible characters, setting, and the conflict of the story; phase two included putting together the plot of the story; and phase three focused on the details of the story, including writing the actual narrative and dialogue. At each phase, the instructor helped the students summarize what they had decided upon thus far, asked questions to help identify potential problems, and suggested directions to take the story. The discussions from each phase of the story were analyzed using the TAMS analyzer as described below.

Research question 3: Understanding and attitudes. Students' understanding of concepts was assessed two different ways over the course of the study. During part one of the study, students got extra credit for their stories if they turned them in the day of the exam that covered the story's concept. Test one included the concepts of science process, force and motion, and energy; test two included electricity, magnetism, sound, and light, and test three included simple chemistry and the solar system. Participants' test questions related to their story's concept were then examined in order to investigate student understanding of the concept after they had written their stories.

For the second part of the study, MOSART pre- and post- test scores related to the stories' concepts were used to assess their understanding of the subject. The MOSART tests were developed and validated by the Science Education Department of the Harvard-Smithsonian Center for Astrophysics. Evidence for validity included iterative review by science education experts and scientists, extensive pilot testing, and data analysis by project psychometrician, Dr. Nancy Cook Smith. Field tests showed a Cronbach's alpha ranging from 0.7 to 0.9 (Coyle, 2009; Cook Smith, 2009).

All students in the Physical Science course take the MOSART K-4 Physical Science test during the first week in the course, and again during the last week of the course. Students' scores on the MOSART pre- and post-tests items related to each of the misconceptions used in the stories were examined, as well as their overall pre- and post-test scores for the test overall. Overall test pre-test means (6.2/10) and post-test means (7.0/10) for all 45 of the students in the course matched the means for the 34 participants in the study. To analyze specific misconceptions by story-concept, the electricity question used was question #1, which used a diagram to determine if students knew how to correctly connect a battery, wire, and bulb in order to light a bulb. The force question used was question #4, which asks what force(s) act(s) on a ball after it is thrown, and the heat question was #8, which asks what happens to heat when one touches a cold doorknob. Alpha reliability coefficients for these items alone was calculated to be $\alpha=0.62$.

Data Analysis

Research question 1. In order to answer the first research question, participants' stories were analyzed using TAMS Analyzer software (v.3.4, 2008), a qualitative analysis software. Each story was entered into the database and open-coded, resulting in two main categories of story components: narrative meaning units and science meaning units. Data were analyzed within and across cases using a phenomenological approach (Creswell, 1998). For this "baseline" phase of the study, narrative meaning units that arose from the data were: characterization, dialogue, plot, and setting. Science concept meaning units for this part of the study included definition, paraphrase, error, and real-life application. An overall description of the "essence" of the phenomenon was developed in order to describe how these preservice teachers approached the task of writing a science story.

Research question 2. Analysis of data for part two of the study began by using similar meaning units to describe the narrative and science elements included in the students' story-creating discussions. As guidance from the instructor was included in the portion of the study, some students in each group did use all of the narrative elements described above for each completed story. To further analyze the discussions, the narrative meaning units used for the second part included "general" and "specific" categories of character, setting, and plot, as well as dialogue. Science meaning units for part 2 included vague description, correct concept, error, and correction of another student's error. Again, the discussions and finished stories were analyzed using a phenomenological approach in order to form the "essence" of the story-creating process during this second part of the study.

Research question 3. Students' test question results (for the first part) were examined. Participants' responses to test questions that assessed the concept in their stories were examined, and the number of correct responses to story concept-related questions was related to participants' overall grade on the exam. Trends were noted and compared to narrative and concept trends in the stories. For the second part of the study, MOSART pre-and post- test scores related to their story concept were examined to determine if evidence of increased understanding of the concept existed.

Results

RQ1: Baseline- The Stories They'd Tell Without Guidance

A summary of the types of stories, including the science concepts described, is presented in Table 1. The concepts that students chose to focus their stories tended to cluster around several basic ideas. The table arranges the stories in the chronological order by exam. Seven students wrote stories on concepts covered in the first test (including motion, force, and inertia);

thirteen students wrote stories on test two concepts (including heat, electricity, and magnetism), and two students wrote stories on test three concepts (physical changes and meteoroids). Two stories, including Chrissie's electricity story and Gwen's heat story, showed some lack of audience awareness: the stories were supposed to be designed for children, but Chrissie's story described an electrocution and Gwen's described how "you" could walk on burning coals.

[Insert Table 1 about here]

Table 2 summarizes how the students told their stories, including the narrative elements included and how the concept was addressed within the story. Narrative elements were coded in each story. Of the narrative elements, three were considered to be "basic" to the telling of a story: character, plot, and setting. Twelve of the 22 stories included at least these three elements, including stories by Deadra (force), Honey (heat), Flower (heat), Katie (magnetism), Janine (magnetism), and Suzy (meteoroids), all of which also included the additional element of dialogue. Ten stories had fewer than the three basic elements: of these, one contained only plot, four contained character and plot, four contained plot and setting, and one contained character, dialogue, and plot.

[Insert Table 2 about here]

Participants approached writing about the science concept in different ways, with some apparent trends. Susan (force), Gabriella (motion), Latisha (electricity), Deadra (heat), Annie (heat), and Anna (physical change) wrote a paragraph or two relating an incident, such as brushing one's hair and noticing sparks, including little plot or description, and often no attempt at characterization. These brief attempts included little to no direct discussion of the science concept they were supposed to demonstrate. All of these stories were short examples of how a particular concept appears in everyday life without explanation. Other stories (i.e., Janine (magnetism), Susan (electricity), Deadra (force), and Nosmo (inertia)) included many narrative elements, but neglected to include direct mention of the science concept. Gwen (heat), Hope (heat), and Chrissie (electricity) included less than three narrative elements, but their stories included a discussion of the science concepts. The remaining stories included both narrative elements and science concept elements.

Errors in science were found in the stories of Gwen (both inertia and heat), Nosmo (inertia), Honey (heat), and Suzy (meteoroids). In the case of Gwen, Honey, and Suzy, the errors were probably based on syntax problems rather than misconceptions, because their subsequent discussions of the concept show understanding. In Honey's heat story, she wrote, "the hardwood floors were cold on [the character's] feet because the heat from his warm body was moving to the floor." Honey seems to mean that the hardwood floors *felt* cold to the character because of heat's movement, but the way it was written could be interpreted (wrongly) that the reason the floor was cold was that the heat was moving towards the floor. In her explanation of her story, however, Honey described the proper conception. Suzy's story confused "meteors" with "meteoroids," and Gwen describes how Newton "proved" his first law of motion. Both Suzy and Gwen show understanding of the proper conceptions in their description of their story concepts. Nosmo, however, demonstrated a misconception about inertia, treating the property as a force throughout the story (e.g., "inertia was greater in magnitude compared to friction").

RQ2: How Did Guidance and Collaboration Change the Stories Students Told?

The second part of the study allowed students to collaborate to create stories, with guidance throughout the process from the instructor. This guidance included choosing the story concept and the misconception that should be at the "heart" of the story, though students had freedom to choose how to tell the story. During the discussion, the instructor would post comments on the discussion boards such as, "Don't forget that the misconception you're trying to address is that a sweater makes you warm. Keep that in your heads while you're writing," or "use dialogue whenever possible…people have an easier time reading dialogue rather than endless long paragraphs where it says, John did this, then Gary did that…" in order to guide the students in writing the story. The instructor edited (mostly for grammar) during the final phase of story writing.

As noted above, instructor guidance made it clear that students needed to include narrative units such as characterization, setting, plot, and dialogue, and so each of the stories contained all of these narrative elements. Analysis of how students told the story was then shifted to examining the extent to which students included more detail in their stories. The phase structure of the discussions allowed students to start out by suggesting general narrative elements, such as "the characters should be a family of four," and later build these generalities into specifics (e.g., "Maybe the son, Edmund, could be 14 and the daughter, Althea, could be around the age of 8 so there is some relation to the readers if they are younger. Maybe Edmund and Althea don't get along just like ordinary sibling rivalries…"). As a result, the depth of characterization, plot, and dialogue was more pronounced than in the stories written during part 1 of the study, and students strove to include each others' ideas whenever possible. For example, in an electricity story, one student suggested that the characters include a family on a picnic, and another added that the picnicking family could be "time warped" back to a time before there was electricity. A third student commented, "I really like the idea of the time warping. I was thinking that instead of them going on a picnic they could be going camping that way they have a lot of food and materials to construct electricity. They could be trying to look for a location to camp at and they lose a child in the forest and they all go looking…" The third student uses the family from the first student (including the names she had chosen) and the time-warping idea of the second student, but built upon the ideas so that more materials (like a flashlight) would be available to the family. Subsequent students would add on to the idea of the camping family, changing details as they wrote.

Table 3 summarizes the science meaning units from the second part of the study. Units labeled "science background" included comments that suggested ways to incorporate the science concepts into the story, though the comments themselves did not often include an explanation of the concept. For example, a science background comment from the electricity story (Time Warp Cave) was, "…they forgot a flashlight so they have to make one before they can fix the radio that will help them escape (we could address misconceptions here about circuts (*sic*)). The radio's wires could be disconnected from the battery and they all have to figure out how to reconnect the wires to make it work!" In addition, instances in which students both correctly and incorrectly described or explained science concepts were coded. Finally, statements that only vaguely referred to a science concept, without demonstrating any understanding of the concept, (e.g., "After the friends have made their game plan and incorporated their new plan to use theories of force they get ready to go to the field" from the force (Newtons vs. Friction Fighters) story) were coded as vague science.

[Insert Table 3 about here]

RQ3: Do Stories Contribute to Understanding?

Baseline group. Table 4 summarizes the performance of each story-writing participant on tests they took after writing the story, including a summary of topic-related question performance and overall test performance. It is easier to determine which stories did NOT provide evidence for helping participants understand the concept by examining participants' test scores. Those participants that answered approximately the same percentage of story concept questions correct as they scored overall, or who scored less on story concept questions, probably did not use the story writing process to enhance their understanding of the concept. With the exception of Milo, the students who did not have evidence for using stories to gain understanding all either did not discuss the concept in the story or had errors in their stories.

[Insert Table 4 about here]

Additionally, examining test scores overall relative to responses on test items on story-concepts reveals that students who scored around the mean for the exam (the "average" test grades) show more evidence for using the stories to understand concepts than either those students with below-average tests grades or the students with above-average test grades. Students who scored below-average on the test tended to show little evidence either way, and students who scored above-average on the exam were almost evenly split between those who did about the same on story-concept questions as on the test, and those who did worse on story-concept questions than they did overall.

Guided/collaborative group. In order to determine the extent to which learning gains were made in the second part of the study, MOSART pre- and post-tests were examined. Specific questions that dealt with the misconceptions on which the students were asked to focus were selected from the MOSART as described above, and percentages of students from each story group that answered each question correctly were calculated. Results from these questions are summarized in Table 5 below. Those students who chose to write a story about electricity did show an increase in understanding on the MOSART item related to electricity, whereas the other students showed no change. However, the electricity groups also showed increased understanding for both force and heat misconceptions, though they did not write stories for those topics. Interestingly, the students who wrote heat stories were those who performed the worst on that question on the pre-test. Each group of students' understanding of this concept appeared to increase during the course, however, and the increase for the heat story-makers was not significantly different from that of the general group.

[Insert Table 5 about here]

Discussion

Unguided Stories and Understanding

When given little guidance, the science stories submitted by the students varied widely in narrative elements and content. Some participants (i.e., Deadra (force), Gwen (heat), Flower (heat)) wrote stories that were essentially re-tellings of story-examples that I used in lecture. Others (e.g., Janine (magnetism), William (electricity)) wrote elaborate stories (either in setting or characterization) that either did not address the concept directly (Janine) or addressed it in a detailed manner (William). Most stories, however, fell somewhere in the middle. Typically, the students who wrote detailed stories including references to the story concept were also those who performed well on exams overall, but students who wrote brief stories without much narrative content performed at every level (below, average, and above) on the exams.

Extra credit was used as an incentive for students to write the stories, but there was an alternative extra-credit assignment the students could have done if they wanted the extra credit without wanting to write a story. Presumably, the students who chose to write a story to get their extra credit either (a) enjoyed the idea or the process of writing a story, or (b) thought that writing a story would be "easier" than the alternative assignment (which I had tried to design in such a way that it would take up about as much time). The intention of this design was to allow those students who did not feel capable of writing a science story to "opt out" without penalty, leaving only those students who felt comfortable with the idea of a science story. Clearly, however, students showed varying levels of ability in constructing a science story, which may indicate that they either do not fully understand how to construct a story, or they have difficulty incorporating science in a story format. Based on the fact that the target population typically performs well in courses designed to teach reading and writing to students, I suspect the latter may be the more pressing component, but this remains open to argument.

The "essence" of the stories from the first part of the study, then, might be "science and stories don't always mesh." Students seemed to struggle with finding ways to "fit" the science concept in the story, often resorting to inserting definitions into a narrative—which tended to disrupt the flow of the story. For example, Gwen's heat story went from a description of Tom, a fifth grader, deciding to run across heated-up metal, to "The reason the metal burned poor Tom so badly was because metal is a good conductor. A conductor is an object that allows heat to pass through easily…" and the story ended without much fanfare, warnings, or excitement. As noted below, the process of writing this story did not seem to help Gwen understand the concept of heat transfer, despite the fact that she performed well on the exam overall. Perhaps the process of writing the story actually gave Gwen a false sense that she understood the concept.

The students who seemed to show the most evidence for increased understanding of their story-concepts were those who performed around the mean on the exams. Students who scored below-average on exams did not seem to be helped or hurt by writing a story, and above average students (like Gwen) sometimes showed evidence that they understood their story-concepts LESS than other concepts on exams. Overall, then, it seems plausible that writing a story could help preservice teachers enhance their understanding of science concepts, but like their future students, these teachers need guidance that is appropriate for their level.

How Does Guidance and Collaboration Improve Preservice Teachers' Science Stories and Understanding?

As expected, instructor guidance helped students write stories with more detailed narrative elements. However, the process by which students put together the science in the stories became more apparent when the discussions were visible. As in the first part, students in the second part of the study did show some evidence of struggling with the science concepts they were supposed to address: including scientific errors in their ideas, writing vague descriptions of the science concept indicating rather weak understanding, or neglecting the science concept altogether while focusing on the narrative components of the story. However, the group dynamic in part two of the story seemed to help students work on articulating the concept more clearly, and only the "force" story showed many instances of vague or incorrect science. In the electricity and heat cases, when students wrote comments or suggestions for the story that contained vague or incorrect science descriptions, other students in the group often followed up that comment with a more precise explanation or suggestion. There was only one occasion in which a student commented directly that another student's conception was incorrect—in all other cases, students would cushion their corrections with statements such as "or maybe it would be better to have [more correct conception]."

As Table 5 shows, however, there is not any significant evidence to indicate that the process of writing the story helped the students to learn the science concepts, even with guidance. Although most groups of students showed evidence of increased understanding of the story-concepts, this increase tended to occur for other concepts as well.

The essence of the stories from part 2 is "collaboration helps students see the science." Although the number of students involved in some stories allowed some students to participate very little, many students participated in each discussion to a greater degree than required for the grade. Some students seemed willing to step in and be "science experts," to introduce and paraphrase science concepts and bring other students back to the science concept when their ideas started to wander. Some students contributed initial ideas, and others participated more in the construction of the narrative and dialogue. The collaboration was key—participants had to take the time to read the comments of other participants in their groups in order to put together a cohesive and engaging narrative. The group whose story did not make it to a final phase had difficulty collaborating- the story branched off into two or three different plot lines, each with different characters. Since each of these "sub-stories" had only one or two writers, none of the "final" sub-stories were complete, and all contained vague science.

Why Use Stories?

If, as noted above, there is not significant evidence that writing stories with guidance helped the preservice teachers understand the science concepts, what purpose could these stories serve? First, the stories helped the instructor see where students were confused or unclear about the concept by examining their discussions, and in the guided part of the study, help groups of students develop a more scientific understanding. Second, the story-writing processes helped the instructor understand which concepts seemed to more clearly lend themselves to science stories.

In both parts of the study, force was a concept with which the students struggled. Despite having four five lecture/ discussion periods and two lab sessions focused on forces, the students in the course seemed to have a great deal of difficulty articulating understanding of the concept in a narrative form. The second part of the study, in particular, showed evidence of students' somewhat vague understanding of what forces are acting on a ball that is thrown, and what could cause these forces to change. Students wrote comments in the discussion such as "[the character] brings up Newton's Law of Motion…to help everyone understand how this could help win the game." No additional descriptions were included about which law of motion she is referring to, or how knowing a law of motion could help one play baseball. Another student responded that the pitcher could have "equations…running through his head" while he pitched, with no additional explanation. Instructor guidance was particularly important in these instances: with prompting, the instructor could get the students to reveal some of their misconceptions during the process, and set about correcting them with the help of other students and the instructor.

On the other hand, heat stories seemed to help many participants understand the concept. The concept of heat, by itself, is perhaps a more "tangible" idea than forces, and it was a topic frequently chosen in the first part of the study. The students who chose to write heat stories in the second part of the story tended to be students who performed the worst, overall, on the MOSART pre-test (see Table 5), and their story discussions included the fewest science-related comments (see Table 3). However, students were able to write focused and entertaining stories that addressed a misconception about heat and insulation (i.e., "a sweater will make you warmer"), and in turn showed evidence of understanding the concept more completely on the MOSART posttest. Science stories, then, may be more useful to help preservice teachers understand some concepts more than others, and it is useful to know which topics make more useful stories. The text of some completed stories from the study can be found on the author's website: **http://tinyurl.com/Frisch-science-stories**.

Conclusions from Ritchie et al.'s (2008) study indicated that a teacher can help students collaborate to write a science story, and the scaffolding of the writing process can help students understand and retain science concepts to great effect. In order to use such methods, however, teachers need to be exposed to this type of teaching method, and the preservice stage seems an opportune time to let them try co-writing and collaborating on their own. However, results from this study indicate that many preservice teachers need scaffolding as much as their future students will, and that certain science concepts will work better than others for this purpose. Future work will try to identify more of these "story-ready" science concepts, as well as identify more detailed procedures by which preservice teachers can develop the skills that allow them to co-create science stories and help their students do the same. In addition, I will use interviews to explore the extent to which preservice teachers feel writing stories helps their learning.

Limitations of the Study

Students' story-writing abilities were not controlled for in any part of the study, because I relied on students self-reporting that they enjoyed reading and writing and, therefore, were comfortable with writing a story. However, the study could have been strengthened if students' writing abilities had been assessed using a validated instrument rather than the "baseline" assessment used in part one.

Additionally, the structure of the course itself was something of a limitation, because a great deal of content needs to be "covered" in one semester, so it can be a challenge to integrate new types of pedagogy within an already-packed schedule. However, teaching the stories of science is using science content in context, and thus is a valuable tool for preservice teachers and their instructors to investigate further. With thoughtful planning and scaffolding (perhaps using science trade books as in Ford, 2004), we should be able to help these students use their strengths to help mediate their perceived pedagogical weaknesses in teaching science.

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Author's Note

Final versions of selected science stories can be found on the author's Web page:

http://tinyurl.com/Frisch-science-stories

Appendix A

Directions for Part 1 of Study

EXTRA CREDIT ASSIGNMENT: SCIENCE STORIES

Choose a concept (or two) from the list below:

Static electricity

Current electricity

Ohm's law

Conduction

Convection

Radiation

Electromagnetism

Transverse waves

Sound waves

Light waves

Electromagnetic waves

For your chosen concept(s), write a short story or anecdote. Your story can be based on personal experience, totally factual, totally fictional, or some combination of these. For example, if you have ever been fishing on a lake and noticed the sky darkened and everyone's hair started to stand on end, you might write about that in order to illustrate static electricity. However, you might change the story to include a young boy and/or a young girl, and add some details or some excitement.

Remember that it is important that your story give some kind of illustration or explanation that might help one of your students understand the science concept.

Your story will also need to include the following things:

1. At least one character (can be human, animal, electron, etc. can be you but we'll change your name)
2. Some kind of plot (including conflict- something has to happen to the character)
3. Some kind of resolution or conclusion

Along with your story, please submit your answers to the following questions:

1. How does your story illustrate or explain your science concept?
2. Did the process of writing this story help you understand the concept better than you did before? If yes, how?
3. What are the limitations of your story? In other words, are there some ways that this story might give your students misconceptions or make them confused about the concept?

Appendix B

Directions for Part 2 of Study

The goal of this project is to develop some physical science-related stories as a group. Working on the story together is a great way to help students have ownership over the process of learning a concept, so we're going to try to model that on the discussion boards of WebCT. In order to get credit for the assignment, you will have to make a contribution to each phase of the story. We will decide, as lab groups, on different components of our story to include, so it is important for you to participate in that process, but it is also important for you to make suggestions for us to vote on. In order for your contribution to be considered significant, you will have to include either a suggestion for the story, or an opinion with explanation about which components should be included. The stories' purpose will be dispelling some common misconceptions about electricity, heat, or force. As part of your process, you can decide which misconception(s) you want your story to address.

PHASE ONE: The basics

You will need to make suggestions and express opinions on the following:

MISCONCEPTION: which misconception would you like to address?

CHARACTERS (how many should there be? Name(s)? Gender(s)? Background info?)

SETTING (where should the story take place)?

CONFLICT: What happens to the character(s)? How does this advance the plot?

PHASE TWO: The plot

What should happen in the beginning of the story?

What kind of climax should the story have?

How should the story end?

PHASE THREE: The details

Story dialogue

Story narrative

Story pictures

At the end, I hope to be able to compile little booklets of your story to distribute to all of you. You may find them helpful in your classroom!

Table 1

Types of Stories Told by Participants, Including Concept and General Story Outline

Writer[a]	Science concept(s)	General story
Katie*	Motion (test 1)	Cs experiment with marbles
Gabriella	Motion (test 1)	Cs (dogs) chase each other
Susan*	Force (test 1)	C goes to hockey game
Deadra*	Force, inertia (test 1)	C falls off spinning merry-go-round
Gwen*	Inertia (test 1)	C tries to stop giant rolling cheese ball
Nosmo	Inertia (test 1)	C jumps off a moving golf cart
Milo	Inertia (test 1)	C plays tee-ball
Honey	Heat transfer (test 2)	C notices heat transfer in everyday life
Deadra*	Heat transfer (test 2)	Cs go to beach
Gwen*	Heat transfer (test 2)	C tries to walk on fire
Flower	Heat transfer (test 2)	C notices heat transfer in everyday life

Hope	Heat transfer (test 2)	C describes sand on a special beach
Annie	Heat transfer (test 2)	C plays in snow
Chrissie	Electricity (test 2)	C gets electrocuted and dies
Susan*	Electricity (test 2)	C shocks little brother (static)
Anna*	Electricity (test 2)	C experiments with insulator/conductor
Latisha	Electricity (test 2)	C brushes her hair
William	Electricity (test 2)	C destroys a client's computer
Katie*	Magnetism (test 2)	C gets magnets from school and experiments
Janine	Magnetism (test 2)	C (a compass) gets demagnetized
Suzy	Meteoroids (test 3)	C watches meteorite fall
Anna*	Physical changes (test 3)	C notices physical change in water

[a]story writers' names were changed. Individuals denoted with * wrote more than one story.

C= character

Table 2

How the Participants Told their Stories, Including Narrative Elements Used and Conceptual Units in Each Story

Writer[a]	Science concept(s)	Narrative elements[b]	Concept definition(s)	Paraphrasing of concept	Errors in science
Katie*	motion	C, P, S	✗		
Gabriella	motion	P, S			
Susan*	force	C, P			
Deadra*	force, inertia	C, D, P, S		✗	
Gwen*	inertia	C, P, S	✗		✗
Nosmo	Inertia	C, P, S			✗
Milo	inertia	C, D, P	✗	✗	
Honey	Heat	C, D, P, S	✗	✗	✗
Deadra*	Heat	C, P			
Gwen*	heat	C, P	✗		✗
Flower	Heat	C, D, P, S	✗	✗	
Hope	heat	P, S	✗	✗	
Annie	heat	P, S			
Chrissie	electricity	P, S		✗	
Susan*	electricity	C, P, S		✗	
Anna*	electricity	C, P, S	✗	✗	
Latisha	electricity	P			

William	electricity	C, P, S	✗	
Katie*	magnetism	C, D, P, S	✗	
Janine	magnetism	C, D, P, S		
Suzy	meteoroids	C, D, P, S	✗	✗
Anna*	physical changes	C, P		

[a]Writers names were changed; * denotes participants who wrote 2 stories

[b] narrative element codes: C = characterization, D= dialogue; P = plot; S = setting

Table 3

General Story Structure and Science Meaning Units Recorded for Each Story Written in Part 2

Story	General story	Comments including background science	Comments including correct science	Comments including incorrect science	Comments including vague science
Force (Newtons Vs. the Friction Fighters)	Baseball team uses their understanding of force to win the game	3	1	2	7
Electricity 1 (Time Warp Cave)	Family gets trapped in cave, has to make a circuit in order to escape	8	2	2	1
Electricity 2 (The Science Project Saves Christmas)	The lights don't work before a party, but son's project helps moms fix the problem	7	2	0	0
Heat 1 (The Hot Cocoa Mystery)	Couple figures out how insulators work	3	1	0	0
Heat 2 (Ron's Sweaters)	College student insulates his room with sweaters	1	1	1	0

Table 4

Study Participants' Performance on Story Concept-related Questions on the Test Taken After their Story was Written, and General Performance on the Test Overall

Writer[a]	Science concept(s)	# Topic related test questions correct	Related test grade category[b]	Evidence of increased understanding?	Science meaning units in story?
Susan*	Electricity	2 out of 4	BA	0	Paraphrased
Latisha	Electricity	3 out of 4	BA	0	None
Susan*	Force	2 out of 3	BA	+	None
Deadra*	Inertia	0 out of 3	BA	0	Paraphrased
Deadra*	Heat transfer	2 out of 5	BA	0	None
Janine	Magnetism	1 out of 3	BA	0	None
Milo	Inertia	2 out of 4	A	-	Definition, paraphrase
Flower	Heat transfer	4 out of 5	A	+	Definition, paraphrase
Hope	Heat transfer	4 out of 4	A	+	Definition, paraphrase
Annie	Heat transfer	4 out of 4	A	+	None
Katie*	Motion	3 out of 3	A	+	Definition
William	Electricity	4 out of 4	AA	0	Paraphrase
Gwen*	Inertia	3 out of 3	AA	0	Definition
Nosmo	Inertia	2 out of 4	AA	-	Error
Honey	Heat transfer	4 out of 5	AA	0	Definition,

					paraphrase,
					error
				-	Definition,
Gwen*	Heat transfer	2 out of 4	AA		error
Katie*	magnetism	2 out of 2	AA	0	Paraphrase
				0	Paraphrase,
Suzy	meteoroids	2 out of 3	AA		error
Gabriella	motion	1 out of 3	AA	-	None
	physical			-	None
Anna*	changes	2 out of 3	AA		

[a]Writers' names have been changed; * denotes participants who wrote two stories.

[b]AA = above average (test grade was more than two points above mean test score for the class on that test); BA = below average (test grade was more than two points below mean test score for the class on that test): A = average (test grade was within two points +/- average test grade for that exam.)

Table 5

Percentage of Students From Each Story Group that Answered MOSART Topic-related Questions Correctly (Topic on Which Story was Written is Highlighted)

	Overall pre-test	Overall post test	Force pre-test	Force post-test	Electricity pre-test	Electricity post-test	Heat pre-test	Heat post test
Force story group (n = 6)	65%	83%	83%	83%	100%	100%	33%	100%
Electricity story 1 (n= 8)	60%	72%	50%	79%	64%	93%	36%	71%
Electricity story 2 (n = 6)	60%	73%	50%	83%	67%	83%	33%	83%
Heat story 1 (n = 6)	58%	70%	83%	50%	83%	83%	17%	67%
Heat story 2 (n = 8)	58%	70%	38%	50%	75%	75%	13%	75%