Proceedings of the Interdisciplinary STEM Teaching and Learning Conference

Volume 1 Article 7

5-2017

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Recommended Citation

Pfiester, Josh (2017) "Using Primary Sources in STEM Education: An Example," *Proceedings of the Interdisciplinary STEM Teaching and Learning Conference*: Vol. 1 , Article 7.
DOI: 10.20429/stem.2017.010107
Available at: https://digitalcommons.georgiasouthern.edu/stem_proceedings/vol1/iss1/7

Using Primary Sources in STEM Education: An Example

Abstract

Primary sources are original artifacts from the past that can used to understand an event or time period. They are customarily only thought of in the realm of historical thinking. That is unfortunate because they can also be considered in terms of scientific, economic, cultural, and mathematical thinking. While primary sources are increasingly taking more prominent roles in the social studies and history classrooms, they are still very rare in other disciplines. This paper describes how primary sources gathered from the Library of Congress were situated in a larger STEM lesson focusing on the challenges faced by WWI veteran amputees. Lesson reflection found that with sufficient scaffolding and other support, primary sources make an excellent resource for STEM teachers. Further, STEM and primary sources make natural partners in teaching and learning because they both have an interdisciplinary nature and tend be applied to real world situations.

Using Primary Sources in STEM Education: An Example

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Acknowledgments: This manuscript was made possible by the author's participation in the Library of Congress Summer Teacher Institute: Science, Technology, and Engineering Focus. Washington, D.C. June 20-24, 2016.

Introduction

American schooling is increasingly moving from the sage on the stage to the guide on the side. This paradigm shift includes allowing students to construct knowledge and make assessments. In this exploratory single exposure study with pre-service teachers, an interdisciplinary lesson was conducted that combined primary sources and a hands-on lesson

Literature Review

Primary Sources

Primary sources are original artifacts based on direct observation that can used to understand an event or time period in terms of historical, scientific, economic, cultural, and mathematical thinking. They can include such artifacts as photos, diaries and journals, musical recordings, and first-hand newspaper accounts (Examples of Primary Sources, n.d.). However, they can also include electronic communication (such as emails and text messages), fingerprints, furniture, and residue containing DNA. The cognitive act of thinking historically via primary source analysis is quite sophisticated as described by VanSledright (2004). Such thinking includes judging primary source perspective which requires assessing the author's social, cultural (and possibly STEM) position. Judging primary source reliability involves comparing it to other accounts of the period. Secondary sources are based on the analysis and interpretation of primary sources and thus one or more steps removed from an event or time period. This literature review is an example of a secondary source.

The classification of a source as primary or secondary is not always clear-cut. That can be seen in the 2013 National Council for the Social Studies document *The College, Career, and Civic Life (C3) Framework for Social Studies State Standards* that states that

> [F]ormer British Prime Minister Winston Churchill's history of World War II is both a primary source, because he was directly involved in some of the events he describes, and a secondary work, because he uses historical sources of many different types to tell the story of developments in which he was not directly involved. (p. 84)

The classification also depends on intent. As an example, textbooks can be viewed as a primary source in a study of how they portrayed women scientists during the Industrial Revolution.

Primary sources engage the learner in a few unique and powerful ways. First, they "engage students both emotionally and personally because the sources represent authentic voices and images" (Stripling, 2009, p. 2). As an example, in one primary source case study titled "Growing-Up before they had to: Children of the Civil War" (n.d.), students analyze primary sources and then answer the following question in paragraph form:

> Through the eyes of the children, what aspects of living through the Civil War would have been most difficult? You must cite evidence to support your answer. Please indicate whether you were satisfied with the evidence and list any additional questions that have been left unanswered through your investigation. (para. 3)

That lesson is a very different cognitive act compared to reading about the American Civil War from a textbook for two reasons: first, it is naturally compelling to children because the sources are from their peers and second, the analysis and interpretation of primary sources is being completed by them

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DOI: 10.20429/stem.2017.010107

(which has been done for them in using the textbook).

The use of primary sources address a complaint John Dewey made about schooling in *The Child and the Curriculum* (1943). He stated that "the various studies, arithmetic, geography, language, botany, etc… embody the cumulative outcome of the efforts, the strivings, and the successes of the human race generation after generation" (p. 12). The way in which science subject matter is often presented to students as "cumulated outcome", they are denied access to the efforts and strivings of scientists. Primary sources are an excellent tool to get to the efforts and strivings of scientists. As an example, the Library of Congress website allows students to view and analyze the actual hand written "Notebook by Alexander Graham Bell, from 1875 to 1876" (1875). Students can see over the course of those pages the work that eventually revolutionized society via the telegraph and telephone. Using the primary source, students can replicate his experiments themselves, and see Bell as not some distant famous figure from the past but a fellow thinker and tinkerer.

Unfortunately for educators, primary sources often cannot be found at one clearinghouse or website. The fact that they can be fragile and cumbersome and in such places as cemeteries, courthouses, and historical societies makes the work time consuming. Even for secondary social studies teachers, the actual use primary sources seems limited (Hicks, Doolittle, & Lee, 2004). The Library of Congress is making efforts to change that; they now have such primary source sets as "The Inventive Wright Brothers" (n.d) and "Understanding the Cosmos: Changing Models of the Solar System and the Universe" (n.d.), which includes drawings and illustrations by Ptolemy, Copernicus, Descartes, and Galileo. Both sets include primary sources, teachers guides, and recommended analysis tools.

Educational Standards

Educational standards are frequently cited in teachers' lesson plans as evidence of rigor and alignment with the curriculum. A major change regarding standards has come in the state-led Common Core State Standards Initiative (CCSSI) that created standards in mathematics and English language arts. The CCSSI states that "[E]ducational standards are the learning goals for what students should know and be able to do at each grade level. Education standards, like Common Core are not a curriculum" (http://www.corestandards.org). While standards are correctly not a curriculum, they still provide some guidance in reaching learning goals. As an example, a search of the Georgia Social Studies

Georgia Performance Standards for middle school found nine instances that primary sources are mentioned. Clearly, the state standards communicates the appropriateness of using primary sources here.

A search of A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas that served as a founding document for the Next Generation Science Standards (that in analogous to the CCSSI for science standards) for the phrase "primary source" only turned up one instance. It states that by 12th grade students should be able to "[U]se primary or secondary scientific evidence and models to support or refute an explanatory account of a phenomenon" (p. 84). At the state level, the Georgia Science Performance Standards for middle school science found zero instances that primary sources are mentioned. In sum, whereas standards clearly communicate the appropriateness of primary sources in the social studies arena, they are nearly invisible in the science arena.

STEM

There exists a lack of consensus about what STEM education should look like in K-12 education. That can be illustrated in disagreements whether there should be an interdisciplinary or a multidisciplinary focus (Lederman & Niess, 1997). Some have even taken to referring to STEM as a "metadiscipline" (Morrison, & Bartlett, 2009). The literature finds that regardless the disciplines are like treated separately like silos and that often the "E" in stem is often neglected and sometimes misrepresented (Kelly, 2010).

Looking at the work of most STEM professionals blurs the lines between those disciplines. This is seen in Petroski's book *Invention by Design: How Engineers Get from Thought to Thing (1996)*. He states that the "idea that unifies all of engineering is the concept of failure" (p. 89). But failure isn't just in terms of structure that is likely raised in the classroom; Petroski reminds the reader that it can take economic, aesthetic, or environmental forms also.

It appears from the literature that there is a harmony between primary sources and STEM in terms of teaching and learning in that both have an interdisciplinary nature and they both tend be applied to real world situations. What does it look like when they are paired in an actual lesson? That is described below.

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Teaching Questions

The two primary teaching questions asked prior to instruction were:

> **a)** How would pre-service elementary education students respond to the primary source aspect of the lesson?
>
> **b)** How would pre-service elementary education students respond to the hands-on aspect of the lesson?

The teaching questions were answered based on researcher observations and analysis of student worksheets (see Appendix A and B).

Methods

Participants

This 150-minute lesson was taught to a class of twenty-one elementary education students in an elementary science methods and materials course in the semester prior to student teaching.

Procedure

A Google document was created by the instructor prior to class that included twenty five numbered primary sources, all found digitally on the Library of Congress website and focused on some aspect of WWI veteran amputees. The class engaged in a brief discussion about primary sources and then accessed the document using their personal laptops. To increase engagement and accountability, each student was assigned her own primary source to analyze using the Analyzing Photographs & Prints document (see copy in Appendix A). It was adapted from a Library of Congress Teaching with Primary Sources instrument. After approximately twenty minutes of analysis, students shared their work in collaborative groups.

At that point, the discussion pivoted to the engineering design process. This was needed to guide subsequent construction of the prosthetic arms by the collaborative groups. Kelly (2010) found that the optimization step is often neglected in the engineering design process. In this step constraints and criteria are evaluated to guide subsequent prototype construction (and importantly, it replaces trial-and-error). To put this process and step into context for the class, we discussed the criteria and constraints present for Charles Lindbergh in designing *The Spirit of St Louis*, based on Kelly's (2010) identification of the same. Finally, student collaborative groups were then challenged to create a prosthetic arm that could be used to pick up an empty plastic cup and place it on a table (criteria) using only the materials provided (constraints). The materials list is provided in the student guide for the activity (Engineering Design Process: Build Your Own Prosthetic Arm- see Appendix B). The lesson ended with groups presenting their work to their peers.

Discussion

The first teaching question was "how would students respond to the primary source aspect of the lesson?" Based on researcher observations, the students were very engaged with the lesson. Several were disturbed at the lack of respect paid to the veterans in terms of language used such as "pathetic wrecks of war". Half of the students remarked in the Analyzing Photographs & Prints document on the industry and resolve of the veterans to adapt to, and be successful in, civilian life. In the semester prior, the students completed a social studies methods course. It was surprising then that students could recall no prior exposure to primary sources. Considering that fact, providing the Analyzing Photographs & Prints document proved invaluable to the success of this part of the lesson.

The second teaching question was "how would students respond to the hands-on aspect of the lesson?" One element that proved decisive in the success of the prosthetic arms was showing the class a LEGO prosthetic hand created by the instructor (based on "Biomechanical Hand", p. 12). Most of the groups created prosthetic arms the included variations of the hand. Of the seven groups, five were able to create prosthetic arms that accomplished the goal of picking up an empty cup and placing it on the table. Considering this activity was completed on the very last meeting of the semester when student effort and interest usually flags, it was impressive the quality of the arms. All the prosthetic arms have been stored for use in the next semester and it is recommended that other instructors do the same. Subsequent classes may benefit by viewing and building on previous work (a reminder of Isaac Newton's famous reminder of the nature of science in stating, "If I have seen further it is by standing on the sholders [sic] of Giants").

Conclusion

Teachers often incorporate primary sources into history and socials studies with the intention of making the subject "come alive" (Fredette, 2013). However, primary sources can just as easily make other subjects come alive also.

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DOI: 10.20429/stem.2017.010107

Although there are a number of challenges in incorporating primary sources (as described in the literature review) they are well worth the effort. More than ever, students need to see the interdisciplinary nature of the world. The reality is the today's Millennials will change jobs about four times in their first decade out of college according to recent LinkedIn study by Berger (2016). With new jobs may come new disciplines, and thus interdisciplinary skills come into play. Interdisciplinary lessons, like the one described in this paper, should contribute to those interdisciplinary skills.

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Appendix A

Analyzing Photographs & Prints: Prosthetic Arms and WWI

Primary sources are great resources to be used in the classroom, but not just in the context of social studies. Today's lesson will involve primary sources in a STEM lesson around prosthetic arms. This document is adapted from the Library of Congress Teaching with Primary Sources instrument to analyze photos. Analyze each photo using the Observe-Reflect-Question method and record your thinking on the lines provided. For more tips on using primary sources, go to http://www.loc.gov.teachers

Photo # ___________

Observe: Describe what you see. • What do you notice first? • What people and objects are shown? • How are they arranged? • What is the physical setting? • What, if any, words do you see? • What other details can you see?

____

____

____

Reflect: Why do you think this image was made? • What's happening in the image? • When do you think it was made? • Who do you think was the audience for this image? • What tools were used to create this? • If someone made this today, what would be different? • What would be the same?

____

____

____

Question: What do you wonder about...who? • what? • when? • where? • why? • how?

____

____

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DOI: 10.20429/stem.2017.010107

What other questions would you like to investigate related to your photo? How can you find out?

Appendix B

Engineering Design Process: Build Your Own Prosthetic Arm

Challenge: You are a member of a team of three or four students, all working together to design and build a prosthetic arm out of the following materials which are provided to you. The arm must be at least 18 inches in length and be able to pick up an empty upright Styrofoam cup containing a golf ball and release it upright onto a table without spilling the ball. Your team must agree on a design for the arm and identify what materials will be used. Your team should draw a sketch of their agreed upon design prior to construction. Part of the teamwork process is sharing ideas and determining which design your team will go with. Trial and error are part of the design process. There is no "right" answer to the problem - your team's creativity will likely generate an arm that is unique from the others designed in your class.

Resources/Materials: long strips of cardboard, binder clips (different sizes), brads, clothespins, craft sticks, fishing line, coat hangers, paper clips (diff. sizes), pencils, rubber bands (different sizes), tape (clear and masking), twine, LEGOS, Tinker Toys, scissors, drinking straws.

Relevant Standards. Next Generation Science Standards (Ages 11-14)

Engineering Design Students who demonstrate understanding can: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions (standard MS-ETS1-1)

Design process criteria definition:

Design process constraints definition:

Motion and Stability: Forces and Interactions Students who demonstrate understanding can: Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object (standard 3-PS2-1)

Prosthetic Arm Sketches

Pre-Build Individual: Pre-Build Group:

Actual final structure:

Post-Activity Exercise Questions

1. Did you use all the materials provided to you? Why, or why not? Which item was most critical to your robot arm design?

2. How did working as a team help in the design process?

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3. Were there any drawbacks to designing as a team?

4. What did you learn from the designs developed by other teams?