Instructor Perceptions of Using Primary Source Projects to Teach Undergraduate Mathematics Content

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Abstract

This study investigates instructor perceptions of their teaching, as well as their students' learning, obstacles encountered, and methods of implementation from the use of Primary Source Projects (PSPs). PSPs are curricular modules designed to teach core mathematical topics from primary historical sources rather than from standard textbooks. In essence, they are a form of inquiry-based-learning that incorporates the history of mathematics through original sources. We provide an overview of results from two semesters of implementation reports and surveys administered at the beginning and end of the semester by instructors who implemented PSPs in their undergraduate mathematics class.

Keywords: Primary Source Projects, Inquiry-Based Learning, History of Mathematics

Background Introduction and Literature

Mathematics faculty and educational researchers are increasingly recognizing the value of the history of mathematics as an important means to support student learning. Primary sources have long been commonly used in teaching undergraduates in the humanities and social sciences (de Guzman, 2007; Klyve et al., 2011). Yet, while there has been some momentum for the use of primary sources to teach undergraduate mathematics, their use remains limited compared to other disciplines. Reading texts in which individuals first communicated their thinking offers an effective means of becoming mathematically educated in the broad sense of understanding both traditional and modern disciplinary methods (Fried, 2001; Laubenbacher et al., 2015). The use of original sources in the classroom promotes an enriched understanding of the subject, its creation, and its ongoing development for instructors as well as students (Jahnke, 2002; Jankvist, 2013).

Despite the benefits of primary source materials detailed above, and granting the wide availability of such materials via published collections and web resources (Calinger, 1995; Euler, 2015), there are significant challenges to incorporating primary sources directly into the classroom. Using secondary historical sources, such as (Katz, 1998), may suffice to reap some of the benefits of the original works. Yet the use of such sources carries its own difficulties, including the risk of placing too much emphasis on learning the history of mathematics per se, as opposed to using history to support the learning of undergraduate mathematics content.

One approach to addressing these issues is through Primary Source Projects (PSPs), which are curricular modules designed to teach core mathematical topics from primary historical sources rather than from standard textbooks. Each PSP is designed to cover its topic in about the same number of course days as classes would otherwise. With PSPs, rather than learning a set of ideas, definitions, and theorems from a modern textbook, students learn directly from mathematicians such as Leonhard Euler, Emmy Noether, or Georg Cantor. This distinction is

crucial to PSPs: they are not designed to teach history; rather, they use history as a tool to better teach mathematics.

PSPs employ a selection of excerpts from primary historical sources that follows the discovery and evolution of the topic in question. Each PSP contains commentary about the historical author, the problem the author wished to solve, and information about how the subject has evolved over time. Exercises are woven throughout the project, requiring that students actively engage with the mathematics as they read and work through each excerpt. At appropriate junctures, students are also introduced to present-day notations and terminology and are asked to reflect on how modern definitions have evolved to capture key properties of solutions to problems posed in the past. Learning from the PSP via in-class activities and discussions replaces standard lectures and template blackboard calculations. PSP implementation helps promote more active learning via primary-source lessons, thereby making it an important form of inquiry-based learning.

Research Questions and Methods

To understand and evaluate the use of PSPs in the classroom, it is important to understand how teachers might implement them in their own classrooms, and how the implementation of PSPs may benefit teachers and students. This information is useful for educators who want to incorporate this new perspective in their teaching, and serves as an important contribution to the broader literature on inquiry-based learning.

To further explore these broader questions related to PSPs in the classroom, we recruited instructors of undergraduate mathematics to serve as "site-testers" through training and implementation of PSPs in their own classrooms. Teachers served as site-testers in either a fall or spring semester taking place over the course of an academic year. We surveyed teachers before and after the implementation period to further understand the efficacy of implementing these materials in real classroom contexts. We also gathered demographic information on teachers and asked them more broadly about their experiences implementing PSPs (the challenges they faced, the reaction of students, etc.). We aim to address several key questions designed to deepen our understanding of various aspects of faculty implementation of PSPs

1. Changes in Instructor Teaching Tendencies. How might the implementation of PSPs change instructors' perceptions about their own teaching behaviors and tendencies? How do instructors perceive/describe their implementation of PSPs as compared to their typical classroom teaching?

2. Instructors' Perception of the Impact of PSPs. Describe instructor's reported impacts of the implementation of PSPs on (1) perceptions of instructors concerning their students' knowledge of mathematics and its history, and perspectives and attitudes towards the subject; and (2) perceptions of instructors concerning the genre of their teaching and specific instructional practices.

3. Implementation of PSPs. Describe how PSPs are implemented, including modifications made to the PSP to meet the individual needs of their classrooms. What obstacles, if any, do instructors perceive to the successful implementation of PSPs?

Recruitment of Site-Testers

Site testers were recruited in a variety of ways. Seventeen of the site testers had attended a prior site-tester workshop, and we advertised using email listservs of groups likely to include people interested, such as the History of Mathematics Special Interest Group of the Mathematical Association of America (MAA), some geographic sections of the MAA, the MAA's Project New Experiences in Teaching (NExT), and the Americas Section of the International Study Group on

the Relations between History and Pedagogy of Mathematics. Further recruiting was conducted through regional workshops, talks, and informal networks.

Data Collection and Analysis

We collected a variety of data from instructors before and after they implemented PSPs in their classrooms. Each of these data sources serves to address the specific research questions summarized above. Our data comes from four primary sources: the initial site-tester application, a pre-course survey, a post-course survey, and an implementation report from each PSP tested.

Pre-course survey. By the end of their first week of class, site testers completed a pre-course survey (through a series of Likert scale questions) that focused on instructors' perceptions of their own mathematics instruction (e.g. typical classroom structure, typical instructional goals, etc.), instructors' perception of their students (e.g. typical instructional assumptions made about their prospective students while lesson planning), and general descriptive information (e.g. professional rank, courses taught, etc.).

Post-course survey. During the last two weeks of their term, site testers completed a post-survey designed to gather information about instructors' perception of the effects on themselves of utilizing PSPs in the classroom (through a series of Likert scale questions), instructors' perception of the effects of utilizing PSPs in the classroom on the students and general information (e.g., which PSP was implemented, general classroom structure, etc.). The post-survey also contained a series of identical questions found in the pre-survey that targeted instructors' perceptions of their own mathematics instruction in order to assess any changes.

Implementation report. After the implementation of PSPs, instructors also completed implementation reports with a variety of open-ended questions that focused on the their experiences implementing PSPs in their classrooms.

To address Question 1 we first compared the identical items on pre- and post-surveys pertaining to teaching tendencies and behaviors by conducting a series of paired t-tests on each individual question. These comparisons will help reveal whether the implementation of PSPs had any influence on the types of teaching strategies that site testers use in their classrooms. Subsequently, addressing Question 2, we will examine the questions from the post-surveys that asked site-testers directly whether or not they believed the implementation of PSPs had any positive *impacts* on their own understanding/teaching of mathematics, as well as their students' learning. Finally, to address Question 3, we will provide a summary of the type of open-ended feedback instructors provided, along with some representative examples.

Results and Discussion

Results from the pre-course surveys show that 35 participants responded to the Fall 2017 surveys and 25 participants responded to the Spring 2018 surveys; 9 people site-tested in both semesters. These responses to the pre-course surveys indicated participants with a wide range of professorial ranks, teaching experience, current institutional incumbency, and PSP authorship status. We combined data from the two semester surveys for a total of 60 participants who completed both pre- and post-surveys.

Site tester applicants came from 39 different institutions, including public and private four-year universities, primarily research institutions, and community colleges. Site testers generally had between 0 and 35 years of mathematics teaching experience, with a noticeable grouping with 11-15 years of experience.

When asked about their experience with primary historical sources in mathematics, more than half of respondents (26 of 50 = 52%) indicated that they already possessed experience in using primary sources in their research. Significant fractions of respondents had prior experience

using primary source materials in their teaching (18 of 50 = 36% in history of mathematics courses, and 13 of 50 = 26% in other mathematics courses) while about a quarter reported no such experience (12 of 50 = 24%).

Changes in Instructor Teaching Tendencies (Question 1).

To assess whether or not the implementation of PSPs changed instructors' teaching behaviors, we compared identical items on the pre- and post- instructor surveys. The respondents were asked to indicate on a 5-point Likert scale if each item corresponding to a specific teaching strategy was 'very descriptive of my teaching' (5), 'mostly descriptive of my teaching' (4), 'somewhat descriptive of my teaching' (3), 'minimally descriptive of my teaching' (2), or 'not at all descriptive of my teaching' (1). By comparing these identical items on pre- and post-surveys, our goal is to identify any of these tendencies that may have changed as a result of the implementation of PSPs.

Paired t-tests were conducted to identify any significant changes in perceived teaching behaviors before and after PSP implementation. One variable changed significantly before and after PSP implementation; specifically, instructors reported that the use of student questions and comments to determine the focus and direction of classroom discussions reflected their teaching tendencies *more so* after the implementation of PSPs than before, $t(59) = -3.37$, $p = .001$.

Although statistically insignificant, there were three other changes worth noting from the pre- and post-surveys. A noteworthy portion of instructors reported incorporating more time during class dedicated to student discussion of course concepts after PSP implementation ($p= 0.070$). A marginally significant portion of the instructors also reported that they allowed for more time dedicated to student reflection of their problem solving strategies ($p= 0.062$) and inter-student constructive criticism of ideas ($p= 0.057$).

Instructors' Perception of the Impact of PSP (Question 2).

A portion of the post-survey questions were 7-point, Likert-style questions designed to gather information regarding how PSP implementation *impacted* the instructors and their students' knowledge of mathematics, learning/teaching approaches, and beliefs about math. For example, instructors responded to items such as "To what extent do you feel that using PSPs in your class made you more/less open to using different teaching strategies?" Responses greater than 4 indicated favorable responses (in this example's case, 1 = extremely less, 4 = neutral, 7 = extremely more) while responses below 4 indicated non-favorable responses.

PSPs and Instructor Teaching Approaches. Implementers' perceptions of how their use of PSPs affected their own knowledge and beliefs about mathematics tended to be generally positive ($M = 5.12$). Although not all items are shown, Table 2 shows average responses to several questions focused around instructor's teaching abilities and tendencies.

Table 2
Instructor perception of how implementing PSPs affected their teaching. All 60 instructors responded to each question.

To what extent do you feel that using PSPs in your class…	M	SD
made you a more/less versatile teacher?	5.32	0.75
made you a better/worse teacher?	4.95	0.89
did/did not induce you to discuss course topics in a broader context?	5.17	0.91
made you more/less open to using different teaching techniques?	5.13	0.83
increased/decreased your confidence in incorporating history into your teaching?	5.30	0.93

PSPs and Student Knowledge and Learning Approaches. Instructor perceptions of how PSP implementation affected their students tended to relay positive (M = 5.29) trends in terms of their students' increase in knowledge, capacity and appreciation of the history of mathematics and mathematics in general. Table 3 shows average responses to questions focused around the impacts of PSPs on student knowledge and learning (all items are reported on).

Table 3
Instructor perception of how implementing PSPs affected their students. All 60 instructors responded to each question.

To what extent do you feel that using PSPs in your class…	M	SD
increased/decreased your students' knowledge of mathematics?	5.30	0.79
increased/decreased your students' knowledge of the history of mathematics?	5.72	0.64
increased/decreased your students' capacity for different ways of thinking?	5.33	0.71
increased/decreased your students' appreciation of the evolution of mathematics?	5.53	0.79
made your students more/less able to learn in a variety of ways?	5.05	0.77
did/did not provide a way of learning that better fit some of your students' needs?	4.68	1.07
did/did not induce your students to learn topics in a broader context in your classes?	5.32	0.91
made your students more/less open to learning in different ways?	5.07	0.80
made different areas of mathematics seem more/less unified to your students?	5.00	0.99
improved/worsened your students' attitude towards incorporating the history of mathematics into a mathematics course?	5.23	0.93
increased/decreased your students' understanding of the value of studying the history in mathematics for learning mathematics?	5.17	0.94
did/did not provide your students a different perspective on mathematics?	5.63	0.74
increased/decreased your students' appreciation of mathematics as a humanistic endeavor?	5.55	0.91
increased/decreased your students' appreciation of mathematics as a creative endeavor?	5.43	0.91

Implementation of PSPs (Question 3).

Describe in general terms how the PSP was implemented. Themes emerged pertaining to how PSPs were implemented in terms of student work both in and out of the classroom and also the role of the instructor during class time. Emergent themes revealed that instructors gave brief introductions to the material (28%), included instructor-led discussions (24%) and reconvened at the end of class with a debrief (29%) following student group work (40%). Although responses generally did not include these themes in succession, the most frequently reported codes from all responses communicated a general class structure where instructors introduced the material, led the class in discussion, allowed for group work throughout class time

to work through tasks and ended by debriefing their students. PSP implementation generally constituted of one or some combination of the following classroom structural components:

1. Students were assigned preparatory work before PSP lessons were introduced. This work usually came in the form of assigned readings or initial attempts at introductory tasks in the PSP.
2. Some instructors opted to provide a brief introduction to the topics within the PSP as a mechanism to prevent confusion and promote efficiency of PSP completion.
3. Instructors also led class-wide discussions and other activities pertaining to PSP material.
4. Implementation reports also relayed that PSP implementation led to substantial group work on the material.
5. After a class period's work on PSP material, instructors reconvened the class for a short debrief on the material covered that day.
6. Unfinished PSP tasks were generally assigned as homework problems.

This classroom structure substantially echoes the intent of inquiry-based learning approaches that focus on group work, student discussion and less instructor lecturing without losing instructor guidance of their students through the material.

Comparison between PSP implementation and General Instructional Approach. Approximately two-thirds (64%) of instructors reported that their PSP implementation involved some deviation from their general instructional approach in the course. Increased use of group work (32%) and fewer instructor-driven activities (28%) were the most commonly reported differences. In addition, 19% reported "letting go" of their classes more. See the following quotes:

> Implementing PSP in class was very different than my general teaching approach in class. Definitely, more active learning was involved with the implementation and students seemed more interested in math which is not usually the case. It was more student centric and they seemed to join the class more and it was also enjoyable for me.
>
> I have never done something like this before...I have never used a lengthy project like this.
>
> Implementation of PSP showed me the importance of group work.

While 36% of the responses indicated that the PSP implementation did not deviate significantly from their general instructional approach in the class, some commented that they already lead a student-centered classroom. As two instructors noted,

> I would say that this PSP fit in very well with my teaching style, or at least the teaching style that I prefer to use (there are still lessons that are primarily lecture; I try to minimize lecturing, so I really liked having this PSP).
>
> This is not abnormal: I assign reading and exercises for each class. The students answer reading questions and reflect on their reading and questions they have, and they prepare the exercises for presentation..., and we spend class time with them doing presentations, discussing questions they had on the reading, and working in small groups on more problems. They also have an individual homework problem or two assigned after every class.

Overall, instructors reported less instructor-focused activity (e.g. lecturing), more group work and more instructional practices that would align with various active-learning strategies.

Modifications and Obstacles Experienced During Implementation. Instructors tended not to modify the PSP (32%) but still offered suggestions for future implementations (36%). When instructors did modify the PSP during implementation, they either omitted (15%) and condensed (14%) sections to fit into a smaller time frame. These findings suggest that the PSPs selected by instructors were sufficiently well-developed for a variety of classroom settings. When PSPs were modified, it was primarily due to time constraints and not due to material within the PSP. Both findings suggest that current PSP materials are useful.

Approximately 29% of instructors reported that they did not face significant obstacles during PSP implementation. When instructors did face obstacles, they were generally due to instructor inexperience with inquiry-based learning approaches (17%), students' inability or unfamiliarity with reading primary source material (12%) or general timing issues with regard to implementing the PSP (12%). The following quote(s) exemplify these findings:

> I also had to adapt to not lecturing. At times it felt like I wasn't helping them that much.

> The only obstacle is that I need to find a way to integrate it into the course more smoothly. I've had a standard syllabus for some years that doesn't really leave room for more student work. This semester (and last year) I simply imposed the PSP on top of the rest of the homework, which is unfair to the students, but I wasn't willing to make major changes until I was sure I would be continuing to use PSPs in this course. I will make those adjustments next year.

Conclusion

Overall, faculty seem to be reporting positive experiences with the implementation of PSPs in their classroom. Instructors reported perceived benefits for both themselves and their students as a result of PSP implementation. Notably, instructors consistently reported that the implementation of PSPs had numerous positive impacts on their teaching abilities and strategies, while they also consistently reported that implementation of PSPs increased their student's knowledge and understanding of mathematics. Instructors have reported that PSPs changed their perspectives on teaching, and opened their eyes to new approaches and techniques. Historical context also emphasized mathematics as a human endeavor, one full of struggle, perseverance and beauty.

Instructors also perceived that their students enjoyed the introduction of inquiry-based learning approaches as opposed to more traditional lecture-based formats. Many of the challenges that faculty face seem to be commonly reported challenges that faculty face when struggling to use active learning for the first time. Results suggest that we could improve upon providing ongoing support to faculty using PSPs. Future research should look into examining what types of ongoing support systems will most benefit instructors who choose to implement PSPs in their classrooms.

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