INTRODUCING MATHEMATICS TO INFORMATION PROBLEM-SOLVING TASKS: SURFACE OR SUBSTANCE?

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This study employs a cross-case analysis in order to explore the demands and opportunities that arise when information problem-solving tasks are introduced into college mathematics classes. Professors at three universities collaborated with me to develop statistics-related activities that required students to engage in research outside the classroom. This paper will focus on one aspect of the study: a comparison of how the teachers balanced mathematical content with information-problem solving in the tasks that they created. These tasks incorporated mathematics in a variety of ways, ranging from tasks in which the mathematical component was crucial to others where mathematics served solely as a marker of credibility. This research has the potential to provide tools for understanding how to productively incorporate information-literacy instruction into the mathematics classroom without losing sight of mathematical goals.

Keywords: Instructional Activities and Practices, Post-Secondary Education, Technology

Introduction

Mathematics students increasingly occupy an environment in which they enjoy immediate access to varied sources of information outside of the classroom. They can look up vocabulary terms on Wikipedia, find context for a statistics problem by accessing governmental statistics directly, and track down discussions of test problems on various Q&A web-sites. While mathematics instruction has historically been focused on sequestered problem-solving (Bransford & Schwartz, 1999), or the ability to solve problems without any outside aid, an increasing number of mathematics teachers have been actively encouraging students to engage with information-based problems (Walraven, Brand-Gruwel, & Boshuizen, 2008) or those problems that require "students to identify information needs, locate corresponding information sources, extract and organize relevant information from each source, and synthesize information from a variety of sources" (Walraven et al., 2008, p.623). I have previously argued (Erickson, 2015) that the use of information-based problems is not just preferable, but that it is also necessary if mathematics instruction is to help prepare students for the quantitative arguments that they may expect to encounter in their everyday lives (Paulos, 1988; NCED, 2001).

This paper presents a cross-case analysis (Stake, 2013) of three different undergraduate mathematics teacher who work with their students on statistics-focused tasks that require the students to seek out, evaluate, and make use of information that they find online. The use of information-based problems have been studied in the context of science education (Hoffman, Wu, Krajcik, & Soloway, 2003; Wiley, Goldman, Graesser, Sanchez, Ash, & Hemmerich, 2009) and history education (Britt & Aglinskas, 2002) before. These studies reported on experiments that took place apart from classroom instruction and so those who crafted the problems did not need to answer as to whether the problems provided evidence of learning, were congruent with the goals set out in the course syllabus, or incorporated the disciplinary topics to be covered in the class. Accordingly, the present study is unique for two reason: a) it takes place in the context of mathematics instruction, and (b) it was incorporated into ongoing mathematics courses. The analysis of the design and implementation of these information problem-solving math tasks provides a window into the balance teachers must strike between mathematical content and information literacy practices. In particular, the analysis addresses the following research questions:

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1. How does mathematical content function as a component of an information-based problem introduced into a mathematics class which is meant to prepare students for the mathematics that they will encounter in their everyday lives?
2. What opportunities are students given to employ their mathematical knowledge through their work on these information-based problems?

Theoretical Framework

Three different conceptions of literacy have emerged which each highlight the importance of introducing information-based problems to mathematics instruction. (1) A move to attend to how reading and writing is conducted in the disciplines and to use this as a way of thinking about how to teach those disciplines means that mathematics teachers must think more carefully about how those who work in STEM fields locate and evaluate mathematical resources (Schleppegrell, 2007; Moje, 2007; Shanahan & Shanahan, 2012). (2) Quantitative literacy, sometimes described as a mathematical proficiency that can serve any individual in their everyday life, has been embraced as an educational goal, particularly at the undergraduate level (Cullinane & Treisman, 2010; Watson, 2013;MORE CITATION) and seen realization in courses offered by many colleges for non-STEM majors who need to fulfill a mathematics requirement as part of their liberal arts education. (3) Researchers in the information sciences have been arguing for the importance of instruction in order to facilitate college and high school students' ability to effectively research topics online (Rader, 2002).

While the importance of information-based problems for disciplinary literacy is easy to justify as long as one accepts that information-seeking is an important part of practice in the disciplines, it requires a little more unpacking to explain why this type of instruction might have a place in mathematics instruction. One way to begin such an explanation is to imagine an applied mathematics problem -- say students are given an editorial in which the author argues that federal guidelines on fuel efficiency will end up costing the country more money than it will save (Diefenderfer, 2009). Students are asked to read the editorial and then provided with several guiding questions that encourage the students to analyze the numerical argument contained in the article while noting some of the additional information that might be required prior to coming to a final verdict on the validity of the editorial's argument. While this activity is a legitimate applied mathematics problem, the real-world context (see Figure 1) suggests other directions that such a problem could be taken.

If a reader were to actually want to determine whether the editorial's claim was true or not, they would want to locate the relevant *epistemic community* (Haas, 1992), or that community that possesses the expertise to tentatively rule on the truth of the claim. In other words, they would need to engage in the practice of rational dependence by finding experts on whom the students have good reason to rely. The problem as originally stated does not afford the students an opportunity to engage in this practice. They are not asked to seek out and evaluate those sources of information that might either corroborate or challenge the argument found in the editorial. An *information-based problem* (Walraven et al., 2008), on the other hand, requires that the student seek out and evaluate sources outside the classroom. In order to come to a better understanding of an information-based problem, the student must "identify information needs, locate corresponding information sources, extract and organize relevant information from each source, and synthesize information" (Walraven et al., 2008, p.2) in a process called *information- problem solving*. My inquiry can be framed, then, as a question about how mathematics teachers and their students cope with the introduction of information-based problems, and whether and how these problems afford opportunities for the practice of mathematical problem-solving skills.

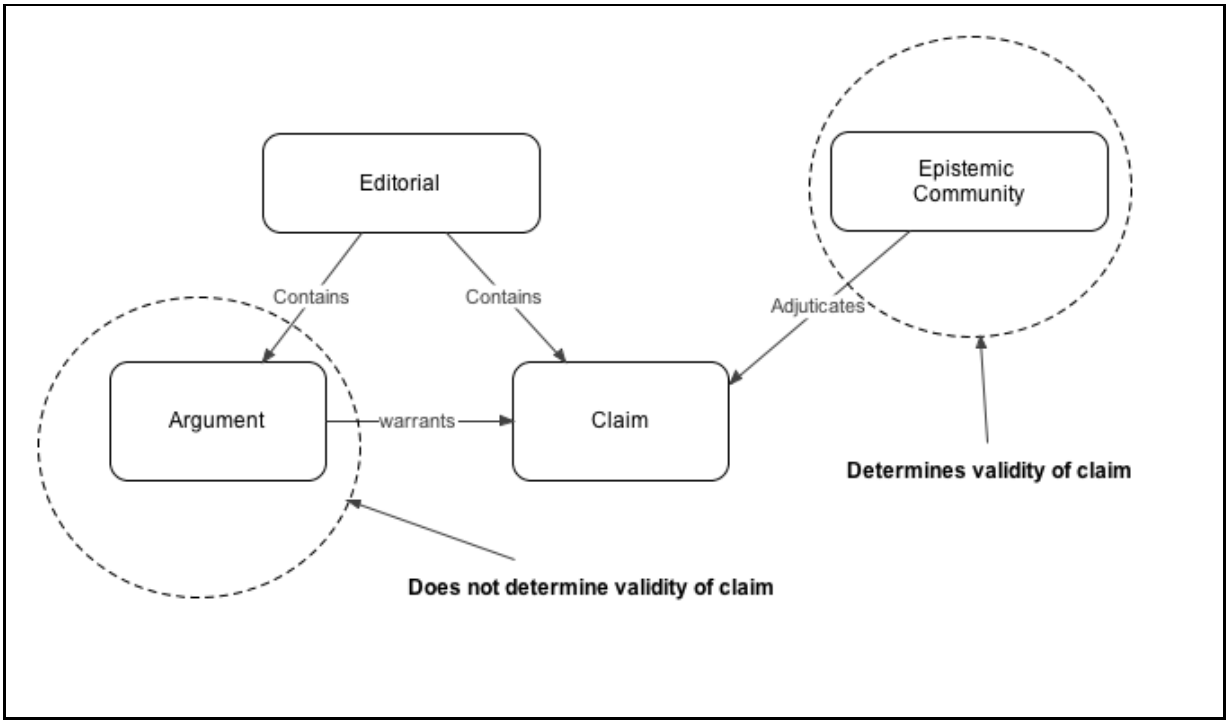

Figure 1. Relationship between editorial, claim, and epistemic community.

Methodology

I began this work by contacting instructors of terminal mathematics courses for non- STEM majors because my reading of the literature and interviews with mathematics educators suggested that this would be the most accessible site for this type of work. There were thirteen educators at ten different institutions who responded to this call and, while they all expressed interest in the idea when I explained it to them, I ended up with 4 collaborating instructors as the others were not able to work with me due to either institutional or timing constraints. I met with each of these four collaborating teachers and explained the rationale behind information-based problems and we worked together to design a couple of activities in which this type of problem would be introduced to their students. The analysis is focused on the three sites (see Table 1) where the instructors had the greatest role in designing and implementing the problems.

At Phi University students were assigned to argue one side in a classroom debate. To prepare, they were required to research their topic and provide some statistical evidence supporting their side of the issue. At Rho University we developed a two-part activity where students were asked to look for articles in which a conjecture about causation was being studied (e.g., vaccines and autism). They were asked to locate the quantitative evidenced used to claim that the two variables were or were not correlated, and then engaged in a small-group discussion with their peers about the topic. Their groups tried to come to a consensus on the issue at stake and then shared their verdict with the rest of the class. The students at Delta University also worked in small groups, but here they were asked to create a presentation in which they would analyze the way that statistics were used in a research article for the rest of the class. The focus of this analysis would be on the sampling methodology, but they were free to talk about other facets of the article if they so chose.

Table 1: Research Sites

University Name*	Course Name*	Students	Topics	Structure
Phi University (Research)	Topics in Mathematics	22 entering Freshman, Liberal Arts Majors	Gun Control, Marijuana Legalization, Single-Sex Education, Death Penalty	Debate Format
Rho University (Regional)	Quantitative Reasoning	14 Juniors and Seniors, many are prospective Nursing students	Autism and Vaccination, The Mozart Effect, Gun Control, Health Care Reform	Small-group Discussions
Delta University (Doctoral)	Mathematics in Today's World	24 Juniors and Seniors, many are prospective Nursing and Education students	Autism and Vaccination, Gun Control, Murder Rate, Vehicular Accidents, Employee Prospects	Small-group Presentation

*These are pseudonyms

This study takes the form of a multi-case analysis (Stake, 2013) derived from the activities described above. The *quintain*, or the phenomenon of interest for this cross-case analysis, is the introduction of information-based problems to an undergraduate mathematics course. The data for this study includes pre- and post-interviews with the instructors at each of the three sites, supplementary interviews with teaching assistants and students, field notes taken while observing instruction prior to the introduction of the information-based problems, video and audio-recordings of the in-class component of the activities, and copies of the work that the students submitted. These data sources informed the writing of individual case reports which were, in turn, used to develop the cross-case analysis. Following Stake (2013), I developed themes based on my research questions that I then used as an analytical lens for the development of case reports for each of the three sites. After writing up the case reports, I cross-referenced case-specific observations (see Table 2 for relevant examples) with the themes of the larger study. This allowed me to warrant theme-based assertions and used those to inform the final cross-case assertions about the introduction of information-based problems to undergraduate mathematics classrooms. The cross-case assertions related to the students opportunities to interact with mathematical content in the information-based problems will be presented below.

The teachers with whom I collaborated were taking on a unique challenge when they decided to introduce information-based problems to their mathematics classroom. While they agreed that their students would benefit from an opportunity to engage in information problem solving, they had to continue to teach their students mathematics through these problems. I intentionally provided very little guidance on this front and the teachers at each of the three locations approached the challenge in distinct ways. In order to describe the role that mathematical work played in these problems I describe the implemented problems as *academic tasks*, a term that encompasses both the perspective of the students as they try to meet the requirements of their assignment and the teachers as they manage the work of their students. I refer to academic tasks using the technical sense employed by Doyle and Carter (1984) where tasks are broadly understood as the “situational structures that organize and direct thought and action” (Doyle & Carter, 1984, p.130) in the classroom and more specifically as components of the curriculum that direct students to use *operations* on *resources* in order to achieve a *product* which is validated by a system of *accountability.* The different role of mathematics in each of the cases is clarified by articulating where it sits within the overarching academic task with respect to the component operations, resources, and product.

Table 2: Examples of Case-Specific Observations from Rho University

Case-Specific Observation A: In the first session, students were searching for articles and then looking for a correlation coefficient within the articles, but they rarely found a correlation coefficient.
Case-Specific Observation B: Students preferred to work with information resources that contained mathematics that they could understand.
Case Specific Observation C: In the first session, the teacher prioritized the identification of a particular piece of mathematical content, the correlation coefficient, to the exclusion of any discussion of the credibility of sources.

Results

The mathematical aspect of the debates at Phi University was fairly circumscribed; it almost existed as a freestanding task of its own within the larger task of the debate. Tim (a pseudonym for their professor) had decided that his students would provide a statistical chart or diagram as part of their argument and that this would tie the problem into the unit on statistics that the class was in the process of covering. In particular, the students would have to create their own graphic rather than downloading it from elsewhere,

> I made the decision at some point that I didn’t want them to just download graphics off the internet because I was worried that if they did that, they would download a bunch of fancy graphics that they didn’t really quite comprehend and then it would be too much information for anybody in the audience to comprehend too. And so I figured the way around that is that I would have them do it, they read the section on how to present data, that’s section two of that chapter, how to present data, ideas on how to present data, and so let’s make them do it. I think that was a good decision. (Tim, 8/14/13, Lines 73 - 79)

I refer to the creation of graphics as an *almost* freestanding task because it still was predicated on some information-seeking in order to locate the sources containing the statistics that would inform the graphics. One way to put this is that the operations that were part of the debate task (for example, using a search engine, scanning search results) provided the resources that would be used for the mathematical task. I refer to the mathematical work as an academic task of its own because it theoretically could exist independently of its role in the debate as long as equivalent resources were made available. Conversely, a debate could have taken place without students having to make use of statistical diagrams. Nonetheless, by introducing this mathematical task, Tim was able to simultaneously avoid the introduction of graphics that could be too mathematically demanding for his students and to create a relatively well-defined mathematical task within the larger information problem-solving task which he would subsequently be in a better position to appraise as mathematical work.

At Rho University, Anne (a pseudonym for their professor) also created a mathematical task that was part of a larger information problem-solving task, but in this case the mathematical work was necessary, at least as Anne conceived it, for the credibility assessment that constituted the larger task.

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As with the students at Phi University, the students at Rho were to submit a product that included the mathematical work (i.e., the identification and interpretation of a correlation coefficient or confidence interval) alongside more ambiguous information problem-solving work (i.e., an assessment of the credibility of the different sources). It was also the case that the search for those mathematical markers could only occur after the students searched the internet in order to collect sources. Thus, we again have a situation where the information-seeking operations on the internet was used to provide resources for the students' mathematical work. There was one small but significant difference in the case of the second problem; those students were required to only collect sources that contained confidence intervals and so the mathematical operation of identifying a confidence interval became part of the information-seeking work. The subsequent classroom discussion constituted another part of the task, or perhaps a second task, which was much more ambiguous in terms of both its product and its operations. By breaking the information-based problems into two distinct activities, Anne was able to collect and evaluate concrete evidence of mathematical work with the written assignment and make that same mathematical work available as a resource for the students' discussions of credibility.

The first problem at Delta University as developed by Ivan (a pseudonym for their professor) was structurally similar to the mathematical sub-task at Phi University in that the students had to first find a source which they would then use as a resource for their mathematical work. The product at Delta University was the students' analysis of the sampling strategy used by poll or research article that they found. The second problem at Delta University was similar as well, but the use of sources was complicated by the fact that the students could not just pick a source and then analyze its contents. Instead, the students were held accountable for finding the data needed for their calculations which meant that their mathematical knowledge needed to mediate their information-seeking work in a way not seen in any of the other cases. By structuring the problems in this way, Ivan made the students' mathematical work the core of the product that they shared with the class. This was reflected in the type of feedback that Ivan provided for his students, he focused much more on the students' mathematical work than either of the other cases.

Looking across the cases (see Table 3 for cross-case observations) it was notable these students only questioned the source of the statistics when explicitly instructed to do so as part of the activity. When the statistics served as evidence for a point-of-view, as in the case of Phi University, students were only concerned with effectively communicating the information that they found to their peers in order to support their argument. Further, when the statistics were being used as evidence, students used the presence of statistical information as a token of credibility for the information source as a whole, and not as an element of the information source deserving critique in and of itself. Ironically, the activities at Phi and Rho University, in which actual mathematical work was very limited, were felt to be very successful by the Tim and Anne, while Ivan expressed some frustration with his activity. This appeared to be at least partly due to the opportunity the presentations afforded for Ivan to observe gaps in his students' knowledge of basic statistical concepts, an opportunity that did not exist at either of the other two locations. In a subsequent interview with Ivan, he expressed some satisfaction that he was able to realize that students did not fully understand some of the more basic statistical concepts that he had been trying to teach them and said that he would incorporate a similar activity into future iterations of the course in order to discover whether students could apply what they were learning to real-world scenarios.

Table 3: Cross-Case Observations About the Role of Mathematics in the Information-Based Problems

Cross-case Observation 1: Students only adopted a critical stance towards the statistics that they found when explicitly demanded by the problem.
Cross-case Observation 2: Students successfully drew on elements of a statistical knowledge base throughout the three cases, but those information-based problems in which mathematical work was prioritized presented a greater opportunity for revealing gaps in student knowledge.
Cross-case Observation 3: The students' mathematical knowledge sometimes conflicted with their ability to assess the credibility of a source. On the one hand, if the students are not asked to engage with the mathematics in question, then it may only serve as a superficial marker of credibility rather than providing insight into the mathematical argument. On the other hand, if a source contained mathematics that the students did not understand, then they might not use that source.

Discussion & Conclusion

These three cases afforded me the opportunity to see some of the ways that a practicing mathematics teacher can dispense their obligation to teach the discipline to their students while assigning non-traditional information-based problems. In all three of the cases, the students had to engage in some initial information-seeking in order to collect sources that would serve as a resource for their mathematical work. In the first case, this work was its own mathematical task, contributing to the larger information problem-solving task but not strictly necessary for its completion. In the second case, the mathematical work was a distinct task but it also served as a resource for the following discussion. In the third case, the result of the mathematical work was actually the product of the information problem-solving task and the students' information-seeking and evaluation played a supporting role.

This analysis of the dilemmas faced by mathematics instructors who wish to create opportunities for their students to build their information literacy skills is not intended to dissuade teachers from using information-based problems that bring students into contact with real-life quantitative claims nor to discourage the introduction of information problem-solving to mathematical tasks. Rather, it suggests that pedagogical choices must be made thoughtfully and deliberately if they are to meet their intended goals.

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