Editorial

So What? Justifying Conclusions and Interpretations of Data

Jinfa Cai, Anne Morris, Charles Hohensee, Stephen Hwang, Victoria Robison,
Michelle Cirillo, Steven L. Kramer, and James Hiebert
University of Delaware

Although often asked tactfully, a frequent question posed to authors by *JRME* reviewers is "So what?" Through this simple and well-known question, reviewers are asking: What difference do your findings make? How do your results advance the field? "So what?" is the most basic of questions, often perceived by novice researchers as the most difficult question to answer. Indeed, addressing the "so what" question continues to challenge even experienced researchers. All researchers wrestle with articulating a convincing argument about the importance of their own work. When we try to shape this argument, it can be easy to fall into the trap of making claims about the implications of our findings that reach beyond the data.

We use this editorial to propose some ideas for presenting and interpreting results with an eye toward addressing the "so what" question. We do so by leveraging the alignment among research questions, theoretical framework, and methods in a well-designed research study. Our aim is to present some practical ideas that could help researchers evaluate their findings with this question in mind.

Aligning Interpretations With Earlier Parts of the Report

In previous editorials, we argued that justifying the significance of a study requires developing a coherent chain of reasoning connecting the theoretical framework (Cai et al., 2019c), the research questions (Cai et al., 2019b), and the research methods chosen to address the research questions (Cai et al., 2019a). In this editorial, we argue that the chain of reasoning is not complete until the results are interpreted and discussed. The results do not stand alone; they fit within the story developed up to that point in the report. Therefore, the importance of the findings—the answer to the "so what" question—depends on the story developed before the results are presented. The importance of the findings, and of the study itself, emerges from interpreting the findings in a way that explicitly connects the data to earlier links in the chain.

Connecting Interpretations With the Research Questions

A first suggestion for connecting interpretations with research questions is that authors carefully consider how their findings address the research questions. Although this might seem like an obvious step in interpreting the data, authors often do not give it sufficient attention, perhaps because answering research questions is deceptively complex. The answers to research questions in mathematics education are (almost) never "yes" or "no." Because educational settings are filled with interactions among multiple, and often confounding, factors, research questions that anticipate a yes or no answer hide important complexities. Appropriate

answers often include tentative observations about why a particular phenomenon occurred, the conditions under which outcomes were found, nuances that require a more complicated answer than expected, or subtle but important differences between the results obtained and the results predicted.

In our March 2019 editorial, we argued that research questions "gain additional significance when they move from only finding answers to the problem to also understanding how and why the answer is a solution" (Cai et al., 2019b, p. 116). Interpreting the findings in ways that help readers understand why the results turned out the way they did is, in our view, a hallmark of interpretations that persuasively answer the "so what" question. How can authors achieve this? One way is to describe the conditions under which the results occurred and offer hypotheses about how the results would be the same or different under different conditions.

The educational significance of describing the contextual conditions under which the results occurred is perhaps most salient for studies that ask questions about teachers' instructional problems. In the future world of research that we previously envisioned, teacher–researcher partnerships pose research questions that directly address pressing instructional problems (Cai et al., 2019b). Understanding the conditions under which the results answer the questions and solve the problems allows partnerships to predict how the outcomes might be similar and different in different classrooms, with different students, for different topics, and so on. In obvious ways, these interpretations lead to further targeted studies. The "so what" question is answered with little additional effort.

How do researchers make sure that the data they collect and the analyses they conduct generate results that can be interpreted in ways that further the field's *understanding* of the phenomena? That is, how do researchers make sure that their research identifies and describes the conditions under which phenomena occur? Most simply, they phrase their research questions in ways that ask about these conditions (Cai et al., 2019b). But how do researchers know what conditions to explore in their research? Answering these questions takes us back to the theoretical framework that motivates, shapes, and justifies the research questions (Cai et al., 2019c).

Connecting Interpretations With the Theoretical Framework

The ultimate answer to the "so what" question is found both in the theoretical framework developed for the study and in the way the results inform the further development of the framework. We previously described several critical functions of a well-constructed theoretical framework (Cai et al., 2019c). One is to answer the question above—under what conditions are particular outcomes expected? Because the theoretical framework is tailored to a particular study, it uses past research to identify the relevant factors that could influence the outcomes and explains why these factors are important. A finely tuned theoretical framework is what allows researchers to pose research questions that ask about the effects of particular factors, and that provides the bases for them to make informed hypotheses about outcomes.

Armed with hypotheses that predict the outcomes and that explain why they are the most likely given the conditions of the study, researchers can interpret the

results in terms of these hypotheses. We view interpreting results in terms of hypotheses to mean examining the way in which hypotheses should be revised to more fully account for the results. For example, if researchers expect Outcome A but instead find Outcome B, they must ask what changes to the hypotheses could have resulted in predicting Outcome B rather than Outcome A. Are there conditions that were not accounted for that should be included in the revised hypotheses? We believe that revising hypotheses is an optimal response to the "so what" question because a researcher's initial hypotheses plus the revisions suggested by the data are the most productive way to tie a study into the larger chain of research of which it is a part.

We view presenting revised hypotheses as a central part of interpreting data and drawing conclusions because revised hypotheses are the touchstones that demonstrate growth in knowledge. Building on other researchers' revised hypotheses and revising them further by more explicitly and precisely describing the conditions that are expected to influence the outcomes in the next study accumulates knowledge in a form that can be built upon and improved by future researchers. Comparing the revised hypotheses with those proposed by previous researchers is a compelling way to answer the "so what" question. These comparisons show how the study advances the field.

Interpreting findings in order to revise hypotheses is not a straightforward task. Usually the hypotheses in any particular study arise from a theoretical framework that blends multiple constructs or variables and predicts multiple outcomes, with different outcomes connected to different research questions and addressed by different sets of data. We previously illustrated some of this complexity in a table (Cai et al., 2019a). In Table 1, we add two additional columns to that table to incorporate findings and justifiable revisions to the initial hypotheses.

Table 1
Coherence Among All Parts of a Research Report

Question	Hypothesis	Data	Analysis	Results	So What?
Research Question 1	Hypothesis 1	Data 1, Data 2	Analysis 1, Analysis 2	Finding 1	Revision of Hypothesis 1
					Future Directions for Study
	Hypothesis 2	Data 2, Data 3	Analysis 3	Finding 2	Revision of Hypothesis 2
					Future Directions for Study
Research Question 2	Hypothesis 3	Data 1, Data 4	Analysis 2, Analysis 3, Analysis 4	Finding 3	Revision of Hypothesis 3
					Future Directions for Study

Not shown in Table 1 is the theoretical framework that underlies the operational parts of a study. The theoretical framework infuses the research questions with meaning and significance; generates specific hypotheses; and suggests methods, data, and analyses that will most directly address the questions and hypotheses. The theoretical framework again comes into play at the interpretation phase as the hypotheses are revised to yield a revised theoretical framework. At the most general level, the answer to the "so what" question is contained in the revisions to the theoretical framework. As we said in the May 2019 editorial:

> Interpreting the findings can then take the form of comparing theoretically grounded predictions to actual results and then refining or extending the theoretical framework to support revised hypotheses that align with what was actually observed. The revised framework can be presented as the study's contribution to the field, and the new, more educated hypotheses can be tested in future studies. (Cai et al., 2019c, p. 222) Comparing the initial and the revised framework allows readers to see clearly the contributions of this study.

Connecting the Interpretations With the Methods

When choosing the best methods to collect and analyze data in a research study, researchers can rely on the educated hypotheses of the theoretical framework to help define what kinds of data will be needed to address the hypotheses, how best to gather these kinds of data, and what analyses should be performed (Cai et al., 2019a). As with the research questions and the theoretical framework, the methods of analysis need to be revisited when one is interpreting the findings. For example, it is important to consider the kinds of claims that one's methods are capable of supporting. This is as true for quantitative analytic methods as for qualitative methods.

Writing the Interpretation and Discussion

Interpreting the findings in ways that move the field forward by addressing the "so what" question is an ambitious undertaking. There also remains the challenge of structuring and writing the discussion to present these observations in a convincing but not overreaching way. In this section, we discuss some of the common concerns that reviewers raise about the discussion. We then conclude this editorial by addressing a challenge that many researchers have faced related to unexpected findings.

Structuring the Discussion Section and Avoiding Common Errors

Although there is no rigid formula for structuring the discussion section of a report, we do see structures that seem to work better than others. We recommend that the discussion begin with a brief summary of the main results, especially those the authors will interpret in the discussion. This summary should not contain data or results not previously presented. The discussion could then move to interpreting the results and addressing the "so what" question in the ways we have described. This makes up the bulk of the discussion. If authors choose to describe limitations in the discussion, they could do so by showing how their interpretations are

explicitly constrained by limitations of the study or they might point to claims they are unable to make. If the authors have chosen to embed limitations in earlier sections of the paper, they will have presented their findings in ways that have already constrained the interpretations of the findings. Finally, the discussion should conclude with the implications of the findings. These implications might suggest directions for future research or applications to educational practice. There could also be methodological implications that inform and enrich the field's toolbox for conducting research.

In our analysis of *JRME* reviewer comments,[1] we found several common concerns that correspond to errors or omissions in the discussion structure outlined above. One common error about which reviewers raised concerns was claiming more than the data showed or could support. Fully 30% of the reviews we analyzed included such concerns. Generally speaking, concerns about the support for claims fell into two categories. On the one hand, reviewers raised concerns about claims for which the authors provided insufficient or unclear support and for which reviewers felt authors could have provided more support by a more extensive or careful analysis of the data collected (e.g., "The authors have collected excellent data, but it must be analyzed and interpreted to provide more meaningful support for the results."). For manuscripts that ultimately received a decision of Accept with Revisions, the majority of reviewers' concerns about support for claims fell into this category. On the other hand, some reviewers raised critical concerns about claims that the data and analysis or the overall design of the study could not support. For manuscripts that ultimately received a decision of Reject, the majority of reviewers' concerns about support for claims fell into this category. Concerns of this type challenge the viability of a manuscript because they involve fundamental breaks in the chain of reasoning that aligns the research questions, the theoretical framework, the methods, and the findings. For example, one *JRME* reviewer stated, "The task given to the participants does not provide the evidence that would be necessary to support these claims." That is, the task was not aligned with the research questions, and the evidence it could provide would not address the claims the researcher wanted to make. In order to address concerns like this, it is typically not enough to simply narrow the claims because the nature of the data and data collection is at odds with the questions and with the theoretical framework the author has constructed. As another *JRME* reviewer commented, "I cannot see how these data would allow a robust analysis within the authors' framework."

Another fundamental but common issue highlighted by reviewers was that the "so what" question was not being addressed satisfactorily. In other words, it was unclear why the contribution of the work being reported was significant or worthwhile, either theoretically or practically. About one third of the reviews for manuscripts that were ultimately rejected included such concerns. As one *JRME* reviewer put it, "The manuscript left me unsure of what the contribution of this work to the field's knowledge is, and therefore I doubt its significance." Even for

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[1] We analyzed the reviews for every manuscript that underwent full review and received a decision in 2017. Reviewer comments in this editorial have been paraphrased to respect the confidentiality of the review process.

manuscripts that were ultimately accepted, 14% of reviews included some concerns about the contribution and significance of the work. However, in many of these cases, rather than posing their concerns as a reason against publication, reviewers offered suggestions to the authors about how to strengthen their argument (e.g., "These suggestions are intended to help the authors make a stronger argument for the contribution of their work" and "I urge you to be more explicit about how your findings are important. What might researchers or teachers learn from your work?").

Dealing With Unexpected Findings

Formulating hypotheses encourages researchers to be explicit and precise about how much is known in the field; it does not preclude researchers from keeping an open mind to observe the full range of outcomes. On the contrary, hypotheses that generate predictions allow researchers to distinguish between those findings they expected to see and those they did not. Researchers are often faced with unexpected and perhaps surprising results, even when they have developed a carefully crafted theoretical framework, posed research questions tightly connected to this framework, presented hypotheses about expected outcomes, and selected methods that should help answer the research questions. Indeed, the unexpected findings can be the most interesting and valuable products of the study. How, then, should researchers treat unexpected findings? Our answer is to treat them in a way that is most educative for the reader.

When researchers are confronted with unexpected findings, we see at least three possible paths that would help the reader understand more fully the phenomenon under investigation. The choice of which path to take depends on the researchers' reevaluation of their own work, a reevaluation guided by their unexpected findings.

The first path we describe is appropriate when researchers reexamine their theoretical framework and decide that it is still a compelling framework based on previous work. They reason that readers are likely to have been convinced by this framework and would likely have made similar predictions. In this case, we believe that it is educative for researchers to (a) summarize their initial framework, (b) present the findings and distinguish those that confirmed the hypotheses from those that did not, and (c) conjecture why the framework was inadequate and propose changes to the framework that would have created more alignment with the unexpected findings. Revisions to initial hypotheses are especially useful if they include explanations about why a researcher might have been wrong (and researchers who ask significant questions in domains as complex as mathematics education are almost always wrong in some way). Depending on the ways in which the revised framework differs from the original, the authors have two options. If the revised framework is an expansion of the original, it would be appropriate for the authors to propose directions for future research that would extend this study beyond its intended scope. Alternatively, if the revised framework is still largely within the scope of the original study and consists of revisions to the original hypotheses, the revisions could guide a second study to check the adequacy of the revisions. This second study could be conducted by the same researchers (perhaps before the final manuscript is written and presented as two parts of the same

report), or it could be proposed in the discussion as a specific study that could be conducted by other researchers.

The second path is appropriate when researchers reexamine their theoretical framework in light of their unexpected findings and recognize serious flaws. The flaws could result from a number of factors, including casting the elements of the framework in too general a way to formulate well-grounded hypotheses or not accounting carefully enough for the previous work in this domain, both theoretical and empirical. In many of these cases, readers would not be well served by reading the chronology of the researchers' flawed or loose reasoning. We believe the reader would learn more if the researchers reconstructed their framework, more carefully built from prior work and in a form closer to that in the first path. If the findings remain unexpected based on the hypotheses generated by this revised, more compelling framework, then the first path applies. But it is likely that the new framework presented in the report will better predict the findings. After all, the researchers now know the findings they will report. The key is for the researchers to show how the new theoretical framework *necessarily* generates the hypotheses and predictions they present in the report. The researchers should then explain why they believe particular hypotheses were confirmed and why others should be revised, even in small ways. The point we are making is that we believe it is acceptable to reconstruct frameworks before writing research reports if doing so would be more educative for the reader.

The third path becomes appropriate when researchers, in reexamining their theoretical framework, trace the problem to a misalignment between the methods they used and the theoretical framework or the research questions. Perhaps the researchers recognize that the tasks they used did not yield data that could have addressed the research questions directly. Or perhaps the researchers realize that the sample they selected would likely have been heavily influenced by a factor they failed to take into account. In other words, the researchers decide that the unexpected findings were due to a problem with the methods they used, not with the framework or the accompanying hypotheses. In this case, we recommend that the researchers correct the methodological problems and reconduct the study.

Summary

This editorial concludes a series of four editorials about conducting and communicating research in (mathematics) education. We have discussed the formulation of research questions (Cai et al., 2019b), the construction of theoretical frameworks (Cai et al., 2019c), the choice of methods (Cai et al., 2019a), and, now, the interpretation of findings. We organized these editorials around three main ideas that permeate the research process: justification, coherence, and significance. Justification is necessary at every step of research, whether in arguing for the significance of research questions, making clear why a methodological choice is appropriate, or convincing readers that one's interpretations of the data are well supported. Coherence requires that all of the components of research fit together into a consistent narrative—a chain of reasoning that connects the theoretical framework, the research questions, the methods, and the ways in which the results are presented and interpreted. An effective choice of theoretical framework can help researchers achieve coherence by providing a structure in which all the parts

of the research can connect. Finally, especially from the perspective of publishing work in a research journal, research must be significant. It must advance our knowledge and understanding of the teaching and learning of mathematics in a substantive and powerful way. With this in mind, we look ahead to our next series of editorials.

In January 2020, to mark the auspicious occasion of the 50th anniversary of *JRME* and the 100th anniversary of the National Council of Teachers of Mathematics, we will begin a new set of five editorials focused on identifying future directions for promising research in the field of mathematics education. In these editorials, our goal will be to identify those research questions that will shape our field's work for decades to come. What do we need to understand better in mathematics education in the next 50 years to improve learning opportunities for all students? As with our previous editorials, we approach this task with a mindset of driving the field forward to conduct research that has the greatest positive impact on the teaching and learning of mathematics in classrooms. In that regard, we have come full circle to the driving theme of our first series of editorials: improving the impact of education research by carefully rethinking the pathways through which education research is conceived, conducted, and communicated (Cai et al., 2017; Cai et al., 2019). We look forward to engaging the field by deliberately considering what we could collectively accomplish in the next 50 years.

References

Cai, J., Morris, A., Hohensee, C., Hwang, S., Robison, V., Cirillo, M., . . . Hiebert, J. (2019a). Choosing and justifying robust methods for educational research. *Journal for Research in Mathematics Education*, *50*(4), 342–348. doi:10.5951/jresematheduc.50.4.0342

Cai, J., Morris, A., Hohensee, C., Hwang, S., Robison, V., Cirillo, M., . . . Hiebert, J. (2019b). Posing significant research questions. *Journal for Research in Mathematics Education*, *50*(2), 114–120. doi:10.5951/jresematheduc.50.2.0114

Cai, J., Morris, A., Hohensee, C., Hwang, S., Robison, V., Cirillo, M., . . . Hiebert, J. (2019c). Theoretical framing as justifying. *Journal for Research in Mathematics Education*, *50*(3), 218–224. doi:10.5951/jresematheduc.50.3.0218

Cai, J., Morris, A., Hohensee, C., Hwang, S., Robison, V., & Hiebert, J. (2019). Research pathways that connect research and practice. *Journal for Research in Mathematics Education*, *50*(1), 2–10. doi:10.5951/jresematheduc.50.1.0002

Cai, J., Morris, A., Hwang, S., Hohensee, C., Robison, V., & Hiebert, J. (2017). Improving the impact of educational research. *Journal for Research in Mathematics Education*, *48*(1), 2–6. doi:10.5951/jresematheduc.48.1.0002