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Editorial

Choosing and Justifying Robust Methods for Educational Research

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In our recent editorials (Cai et al., 2019a, 2019b), we discussed the important roles that research questions and theoretical frameworks play in conceptualizing, carrying out, and reporting mathematics education research. In this editorial, we discuss the methodological choices that arise when one has articulated research questions and constructed at least a rudimentary theoretical framework. Just as the researcher must justify the significance of research questions and the appropriateness of the theoretical framework, we argue that the researcher must thoroughly describe and justify the selection of methods. Indeed, the research questions and the theoretical framework should drive the choice of methods (and not the reverse). In other words, a sufficiently well-specified set of research questions and theoretical framework establish the parameters within which the most productive methods will be selected and developed.

We have argued previously that research should be guided by educated hypotheses—hypotheses about what one expects to find as possible answers to the research questions based on a foundation of earlier empirical and theoretical work. These educated hypotheses shape the choice of methods. One useful heuristic for choosing methods begins with the researchers formulating, as precisely as possible, their set of educated hypotheses about what they will find and the claims that they hope to make. Then, the researchers can work backward to determine what kinds of data would be needed to address these hypotheses and, in turn, what methods would yield these kinds of data. Although this heuristic provides a general blueprint for selecting and refining methods, its benefits can best be understood by examining how it can be applied to avoid many common methodological flaws that arise in manuscripts submitted to *JRME*.

Methodology and Traditional Pathways for Educational Research

In our January 2019 editorial (Cai et al. 2019), we defined research pathways as "the collection of assumptions that define the purposes of educational research, the principles that differentiate research from other educational activities, and the guidelines for how research should be conducted" (p. 2). Manuscripts submitted to *JRME* typically report the findings of mathematics education research studies that follow a traditional pathway for research. That is, the report describes a single study in which the researcher posed one set of research questions and gathered one set of data to answer these questions.

Common Methodological Problems

Based on our analysis of reviewers' comments,[1] one of the most common methodological flaws in 2017 *JRME* submissions was a lack of justification for the chosen methods. For example, one *JRME* reviewer wrote, "The researchers made a number of seemingly random decisions with no explanation." Nearly one third of the reviews for manuscripts that were ultimately rejected included this concern, as did one fourth of the reviews for manuscripts that received a decision of revise and resubmit. In contrast, this concern was raised in only about 15% of reviews for manuscripts that were ultimately accepted. Especially problematic are cases in which authors simply cite other researchers to justify their methods without unpacking the specifics of the methods and presenting an explicit argument for why the methods used are the most appropriate and productive.

Concerns about justifying methodological choices can be attributed, in part, to a lack of alignment among the research questions, the theory, and the methods. As another *JRME* reviewer noted, "The methods need to have more than a cursory connection to the theoretical construct that is at the heart of the study." Indeed, reviewers explicitly highlighted misalignments in one fifth of the reviews of ultimately rejected manuscripts, twice as often as they did for manuscripts that were ultimately accepted or given a decision of revise and resubmit. These misalignments can take many forms, including the scale of the methods not fitting the scale of the research question (e.g., when analyzing too much data interferes with addressing the research question at the appropriate level of depth) or the tasks given to participants not generating responses that directly address the hypotheses (and the associated research questions). Although it may not be obvious when conducting a study, such misalignments become particularly evident in the report. The coherence of the report suffers when authors do not or cannot explain their choice of procedures by connecting them to the hypotheses that constitute the theoretical framework or by showing how the procedures would generate the kind of data needed to address the research questions.

The problem of justification is exacerbated when the methods are not described in enough detail for readers to understand exactly how the data were gathered or analyzed. In roughly 40% of the reviews for manuscripts that were ultimately rejected or received a decision of revise and resubmit, reviewers called for more detailed descriptions of the methods to better understand the choices the researchers made. Even for manuscripts that were ultimately accepted, over one fourth of the reviews called for describing the methods in greater detail. Data coding, in particular, should be described in enough detail to help the reader understand how the researcher interpreted the data with respect to the research questions and the hypotheses (e.g., clearly stating what evidence was needed in order to say a particular code had been satisfied). Coding was a concern in nearly one fourth of the reviews for ultimately rejected manuscripts—double the rate for manuscripts that were ultimately accepted.

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

Several other methodological concerns, including issues of validity, reliability, and considering alternative explanations for findings, were regularly raised in the reviews we analyzed. These concerns are also related to justifying the choice of methods. Although authors sometimes fail to include enough information about how they addressed validity and reliability, that information is essential to making the argument that the chosen methods should produce trustworthy data that address the research questions and that the methods are being executed properly. It is also common for researchers to collect data that do not suffice to rule out alternative explanations for the findings. For example, a qualitative analysis may not make sufficient use of methods like triangulation to challenge and test conclusions, or a quantitative analysis might fail to employ a multilevel model when one is needed, thus leaving open the possibility that the observed results are spurious.

Suggestions for Addressing the Common Problems

The heuristic we proposed earlier—formulate hypotheses about likely answers to the research questions, identify the nature of the data that would address these hypotheses, and develop the data collection procedures that would yield these data—could solve many of these common methodological problems. To demonstrate its usefulness, we elaborate how it might be applied.

We imagine two overlapping but distinct phases in the process of selecting, developing, and refining the methods for a study. The first phase consists of the initial selection and description of research methods through (a) ensuring that the research questions are specified as precisely as possible; (b) formulating predictions or hypotheses (and making explicit one's own implicit hypotheses) about expected answers to the questions based on previous theoretical development, empirical research, and one's own prior experiences; (c) imagining the kinds of data that will be needed to test these hypotheses and answer the research questions; and (d) determining the best ways to gather these kinds of data and analyze them so that the hypotheses can be directly addressed. This phase can also include imagining alternative explanations for the data—alternatives to the initial hypotheses. Doing this helps to ensure that the methods chosen will provide data that can address the competing hypotheses and ultimately support plausible and evidence-based arguments that one hypothesis is more likely to explain the data than another.

Table 1 shows an example of how research questions, hypotheses, data, and analyses should be tightly and explicitly connected both in designing and conducting a study and in reporting the study. In this example, two hypotheses can be formulated for how Research Question 1 will be answered and one hypothesis

Table 1
Coherence Among Research Questions, Hypotheses, Data, and Analysis Procedures

Question	Hypothesis	Data	Analysis
Research Question 1	Hypothesis 1	Data 1, Data 2	Analysis 1, Analysis 2
	Hypothesis 2	Data 2, Data 3	Analysis 3
Research Question 2	Hypothesis 3	Data 1, Data 4	Analysis 2, Analysis 3, Analysis 4

can be formulated for Research Question 2. Several kinds of data (Data 1, 2, and 3) are required to address the hypotheses for Research Question 1, and those data need to be analyzed using three procedures (Analyses 1, 2, and 3). Two forms of data (Data 1 and 4) are required to address the hypothesis for Research Question 2, and they overlap with the data relevant to Research Question 1 as do their appropriate analytic procedures (Analyses 2, 3, 4).

Enacting this systematic process for developing methods will solve a number of the most common methodological problems. The alignment among research questions, theoretical framework (hypotheses), and methods is prioritized as the methods are selected and developed. Documenting this process of methods development can yield a coherent description showing how these key aspects of a research study support each other. In most cases, sufficient detail about the methods can be provided by describing all of the ways the methods are designed to address the hypotheses and, in turn, the research questions.

In our view, the development of research methods can be improved further through a second phase of methods development. The second phase involves iterative, brief cycles of testing the choice of methods and refining them to ensure the most productive methods are used for addressing the research questions. Trying out the methods by gathering and analyzing a small set of data can help researchers quickly determine whether the methods need to be refined. For example, the tasks given might need to be adjusted to generate informative responses or the interview questions might need to be reworded. Perhaps the coding scheme might need to be changed, which, in turn, could suggest changes to the kinds of data that are needed. Even the sample might need to be adjusted or different analytic procedures might need to be selected. Researchers might find it helpful to run through this cycle several times, each time gathering just enough data to identify small tweaks that could improve the chances of addressing the hypotheses and the research questions.

Some specific methodological choices cannot be made or justified properly during the first phase. Data must be collected and some initial analyses must be conducted before final choices can be made. For example, in a study with data that have a nested structure (e.g., students nested in classrooms that are also nested in schools), researchers might decide in the first phase that hierarchical linear modeling (HLM) could be an appropriate quantitative methodological choice to analyze the data. However, it would still be necessary to justify the use of HLM and the chosen model (e.g., the choice of predictor variables or whether the model has two or three levels) through a systematic process of model building in which the model fit is evaluated at each step both quantitatively and with respect to the theoretical framework. This process cannot happen a priori—it depends on having data to analyze in potential models, and would therefore have to occur in the second phase of methods development.

This second phase of empirically improving the methods yields additional benefits. More of the common methodological problems can be resolved. For example, methods can be adjusted to generate the optimal amount of data to address the research questions. Tasks can be sharpened to generate the data most relevant for answering the questions. Further details of method development can be provided and justified based on these pilot tests, model-building processes, or cycles of empirical refinement. In summary, we believe the two phases we have

described can solve many common methodological problems by tightly aligning the research methods with other key aspects of a research study.

We conclude this section by noting that some readers might be concerned that our emphasis on formulating predictions or hypotheses about possible answers to the research questions before conducting a study could preclude researchers from being open to, or aware of, contradictory or unexpected findings. We do not think this is the case. Indeed, we believe that carefully thinking about likely findings creates increased sensitivity to unexpected findings. By making explicit for oneself what one is expecting to find, the likelihood increases that one will notice surprises when they occur.

Methodology and Alternative Pathways for Educational Research

Our first series of editorials spanning 2017–2018 gradually developed a future world of research that aspired to have greater impact on practice. In this vision of the future, we proposed an alternative pathway for mathematics education research that involves teacher–researcher partnerships working on solving problems of practice through iterative cycles of innovation in tasks and lessons. We described in some detail how these teacher–researcher partnerships could operate through multiple phases of work, gradually improving teaching and student learning by iteratively making small adjustments to instruction, gathering just enough data, analyzing the data, using the findings to make further adjustments, and repeating the cycle. The essential elements of this process are similar to the process we recommended above for improving the methods to maximize the benefit of a particular study. We believe this is because empirically based improvement, regardless of the goal, requires similar iterative cycles. In the argument we offered above, the goal is the improvement of methods for maximizing the benefit of a particular study. In the future world of this alternative research pathway, the goal is the direct improvement of classroom teaching and learning. In both cases, researchers form hypotheses, develop methods to test hypotheses, implement the methods to test the hypotheses, use the findings to revise the hypotheses, and repeat the cycle.

A fundamental difference between the traditional and alternative pathways is that the alternative pathway assumes that maximizing the benefits of research (for practice) comes not from a single study, or even from a small number of discrete studies, but rather from a continuing series of connected studies. In fact, the findings from these connected studies constitute the actual findings of interest; they are not just recalibrations of methods developed for a larger study. Rather than being methodological steps on the way to conducting an individual study, the iterative cycles *are* the studies. Task design, implementation and refinement of an intervention, assessment calibration, and revision of hypotheses are the research.

A methodological advantage of the alternative pathway is that, to proceed down this path, many of the common problems cited above must be solved as an embedded aspect of the iterative cycles of work. Engaging in these cycles means that teacher–researcher partnerships are constantly aligning research questions, hypotheses, and methods. They are testing and refining practical hypotheses about how to improve student learning, drawing from both the wisdom of practice and insights from research. The methods used by a partnership in one cycle must be

fully described so the next cycle can build on what the partnership learned and on how they learned it. As we described in an earlier editorial (Cai et al., 2018), the data and artifacts generated by a teacher–researcher partnership should be stored as knowledge packages in a professional knowledge base that is continually updated as the partnership engages in iterative cycles of work. These knowledge packages would hold all the information for other researchers to interpret the partial solutions to the instructional problems that are continuously improved, including the justification and reasoning for the methodological choices made in each cycle.

Although we contend that research that follows the alternative pathway described in our previous editorials avoids many typical methodological pitfalls, we also recognize that this alternative pathway has not yet gained much traction in our field. We expect that as alternative pathways are developed further and implemented more frequently, a new series of methodological problems could appear. We cannot yet address these but we can be quite sure they will be different than those common today. For now, we note one set of methodological questions that may arise: What methods would be appropriate to support generalizations generated by this type of work? For example, if a teacher–researcher partnership engages in numerous cycles of work and produces a set of knowledge packages based around an instructional unit of lessons, how can this knowledge inform another teacher–researcher partnership engaged in work in another content area? Is this work always entirely tied to contexts, or are there generalizations that can inform this work across content areas and lessons? What methods would help to identify such generalizations?

Conclusion

Choosing appropriate and effective methods and justifying that choice is a critical part of conducting and communicating high-quality research in education. By carefully and explicitly connecting the research questions and the hypotheses that form the theoretical framework to the selection of methods, it is possible to avoid many common methodological problems. Indeed, methods that are well justified and closely connected to the other components of the study form the basis for generating trustworthy and insightful findings and for producing a coherent report of the study. If the field moves to other research pathways, many current methodological problems might be solved. But, new problems are likely to arise that require a similar degree of attention.

In our November editorial, we will turn our attention to issues of *interpreting* findings in educational research. For example, we will consider how to avoid the common pitfall of making claims that are insufficiently supported by data, both in research that follows the traditional pathway and in the cycles of iterative work that make up the alternative pathway. Indeed, this is frequently an issue with manuscripts submitted to *JRME* that are ultimately rejected. We will argue that the heuristics for choosing and justifying methodology that we have described in this editorial can also help researchers ensure that their claims are well supported by their data.

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