Chapter 2
How Do You Formulate (Important) Hypotheses?

Part I. Getting Started

We want to begin by addressing a question you might have had as you read the title of this chapter. You are likely to hear, or read in other sources, that the research process begins by asking *research questions*. For reasons we gave in Chap. 1, and more we will describe in this and later chapters, we emphasize formulating, testing, and revising hypotheses. However, it is important to know that asking and answering research questions involve many of the same activities, so we are not describing a completely different process.

We acknowledge that many researchers do not actually begin by formulating hypotheses. In other words, researchers rarely get a researchable idea by writing out a well-formulated hypothesis. Instead, their initial ideas for what they study come from a variety of sources. Then, *after* they have the idea for a study, they do lots of background reading and thinking and talking before they are ready to formulate a hypothesis. So, for readers who are at the very beginning and do not yet have an idea for a study, let's back up. Where do research ideas come from?

There are no formulas or algorithms that spawn a researchable idea. But as you begin the process, you can ask yourself some questions. Your answers to these questions can help you move forward.

1. What are you curious about? What are you passionate about? What have you wondered about as an educator? These are questions that look inward, questions about yourself.
2. What do you think are the most pressing educational problems? Which problems are you in the best position to address? What change(s) do you think would help all students learn more productively? These are questions that look outward, questions about phenomena you have observed.
3. What are the main areas of research in the field? What are the big questions that are being asked? These are questions about the general landscape of the field.

J. Hiebert et al., *Doing Research: A New Researcher's Guide*,
Research in Mathematics Education,
https://doi.org/10.1007/978-3-031-19078-0_2

4. What have you read about in the research literature that caught your attention? What have you read that prompted you to think about extending the profession's knowledge about this? What have you read that made you ask, "I wonder why this is true?" These are questions about how you can build on what is known in the field.
5. What are some research questions or testable hypotheses that have been identified by other researchers for future research? This, too, is a question about how you can build on what is known in the field. Taking up such questions or hypotheses can help by providing some existing scaffolding that others have constructed.
6. What research is being done by your immediate colleagues or your advisor that is of interest to you? These are questions about topics for which you will likely receive local support.

Exercise 2.1
Brainstorm some answers for each set of questions. Record them. Then step back and look at the places of intersection. Did you have similar answers across several questions? Write out, as clearly as you can, the topic that captures your primary interest, at least at this point. We will give you a chance to update your responses as you study this book.

Part II. Paths from a General Interest to an Informed Hypothesis

There are many different paths you might take from conceiving an idea for a study, maybe even a vague idea, to formulating a prediction that leads to an informed hypothesis that can be tested. We will explore some of the paths we recommend.

We will assume you have completed Exercise 2.1 in Part I and have some written answers to the six questions that preceded it as well as a statement that describes your topic of interest. This very first statement could take several different forms: a description of a problem you want to study, a question you want to address, or a hypothesis you want to test. We recommend that you begin with one of these three forms, the one that makes most sense to you. There is an advantage to using all three and flexibly choosing the one that is most meaningful at the time and for a particular study. You can then move from one to the other as you think more about your research study and you develop your initial idea. To get a sense of how the process might unfold, consider the following alternative paths.

Beginning with a Prediction If You Have One

Sometimes, when you notice an educational problem or have a question about an educational situation or phenomenon, you quickly have an idea that might help solve the problem or answer the question. Here are three examples.

You are a teacher, and you noticed a problem with the way the textbook presented two related concepts in two consecutive lessons. Almost as soon as you noticed the problem, it occurred to you that the two lessons could be taught more effectively in the reverse order. You *predicted* better outcomes if the order was reversed, and you even had a preliminary rationale for why this would be true.

You are a graduate student and you read that students often misunderstand a particular aspect of graphing linear functions. You *predicted* that, by listening to small groups of students working together, you could hear new details that would help you understand this misconception.

You are a curriculum supervisor and you observed sixth-grade classrooms where students were learning about decimal fractions. After talking with several experienced teachers, you *predicted* that beginning with percentages might be a good way to introduce students to decimal fractions.

We begin with the path of making predictions because we see the other two paths as leading into this one at some point in the process (see Fig. 2.1). Starting with this path does not mean you did not sense a problem you wanted to solve or a question you wanted to answer.

Notice that your predictions can come from a variety of sources—your own experience, reading, and talking with colleagues. Most likely, as you write out your predictions you also think about the educational problem for which your prediction is a potential solution. Writing a clear description of the problem will be useful as you proceed. Notice also that it is easy to change each of your predictions into a question. When you formulate a prediction, you are actually answering a question, even though the question might be implicit. Making that implicit question explicit can generate a first draft of the research question that accompanies your prediction.

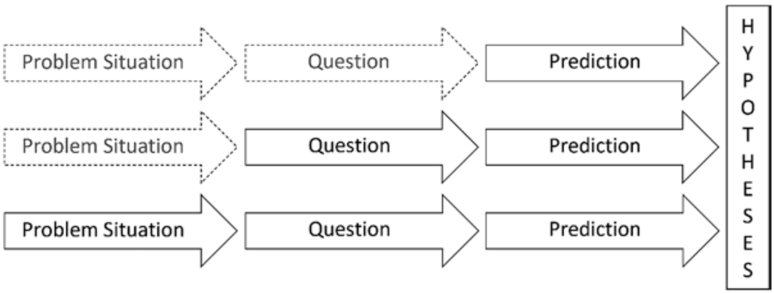

Fig. 2.1 Three Pathways to Formulating Informed Hypotheses

For example, suppose you are the curriculum supervisor who predicts that teaching percentages first would be a good way to introduce decimal fractions. In an obvious shift in form, you could ask, “In what ways would teaching percentages benefit students’ initial learning of decimal fractions?”

The difference between a question and a prediction is that a question simply asks what you will find whereas a prediction also says what you expect to find.

There are advantages to starting with the prediction form if you can make an educated guess about what you will find. Making a prediction forces you to think *now* about several things you will need to think about at some point anyway. It is better to think about them earlier rather than later. If you state your prediction clearly and explicitly, you can begin to ask yourself three questions about your prediction: Why do I expect to observe what I am predicting? Why did I make that prediction? (These two questions essentially ask what your rationale is for your prediction.) And, how can I test to see if it’s right? This is where the benefits of making predictions begin.

Asking yourself why you predicted what you did, and then asking yourself why you answered the first “why” question as you did, can be a powerful chain of thought that lays the groundwork for an increasingly accurate prediction and an increasingly well-reasoned rationale. For example, suppose you are the curriculum supervisor above who predicted that beginning by teaching percentages would be a good way to introduce students to decimal fractions. Why did you make this prediction? Maybe because students are familiar with percentages in everyday life so they could use what they know to anchor their thinking about hundredths. Why would that be helpful? Because if students could connect hundredths in percentage form with hundredths in decimal fraction form, they could bring their meaning of percentages into decimal fractions. But how would that help? If students understood that a decimal fraction like 0.35 meant 35 of 100, then they could use their understanding of hundredths to explore the meaning of tenths, thousandths, and so on. Why would that be useful? By continuing to ask yourself why you gave the previous answer, you can begin building your rationale and, as you build your rationale, you will find yourself revisiting your prediction, often making it more precise and explicit. If you were the curriculum supervisor and continued the reasoning in the previous sentences, you might elaborate your prediction by specifying the way in which percentages should be taught in order to have a positive effect on particular aspects of students’ understanding of decimal fractions.

Developing a Rationale for Your Predictions

Keeping your initial predictions in mind, you can read what others already know about the phenomenon. Your reading can now become targeted with a clear purpose.

HELPFUL TIP

You can search for chapters or literature reviews related to your research topic in recent research handbooks and compendia or in journals. Reading these will help inform your predictions and provide helpful reference lists of other sources.

By reading and talking with colleagues, you can develop more complete reasons for your predictions. It is likely that you will also decide to revise your predictions based on what you learn from your reading. As you develop sound reasons for your predictions, you are creating your rationales, and your predictions together with your rationales become your hypotheses. The more you learn about what is already known about your research topic, the more refined will be your predictions and the clearer and more complete your rationales. We will use the term *more informed hypotheses* to describe this evolution of your hypotheses.

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Developing more informed hypotheses is a good thing because it means: (1) you understand the reasons for your predictions; (2) you will be able to imagine how you can test your hypotheses; (3) you can more easily convince your colleagues that they are important hypotheses—they are hypotheses worth testing; and (4) at the end of your study, you will be able to more easily interpret the results of your test and to revise your hypotheses to demonstrate what you have learned by conducting the study.

Imagining Testing Your Hypotheses

Because we have tied together predictions and rationales to constitute hypotheses, testing hypotheses means testing predictions and rationales. Testing predictions means comparing empirical observations, or findings, with the predictions. Testing rationales means using these comparisons to evaluate the adequacy or soundness of the rationales.

Imagining how you might test your hypotheses does not mean working out the details for exactly how you would test them. Rather, it means thinking ahead about how you could do this. Recall the descriptor of scientific inquiry: "experience carefully planned in advance" (Fisher, 1935). Asking whether predictions are testable and whether rationales can be evaluated is simply planning in advance.

You might read that testing hypotheses means simply assessing whether predictions are correct or incorrect. In our view, it is more useful to think of testing as a means of gathering enough information to compare your findings with your predictions, revise your rationales, and propose more accurate predictions. So, asking yourself whether hypotheses can be tested means asking whether information could be collected to assess the accuracy of your predictions and whether the information will show you how to revise your rationales to sharpen your predictions.

Cycles of Building Rationales and Planning to Test Your Predictions

> Scientific reasoning is a dialogue between the possible and the actual, an interplay between hypotheses and the logical expectations they give rise to: there is a restless to-and-fro motion of thought, the formulation and rectification of hypotheses (Medawar, 1982, p.72).

As you ask yourself about how you could test your predictions, you will inevitably revise your rationales and sharpen your predictions. Your hypotheses will become more informed, more targeted, and more explicit. They will make clearer to you and others what, exactly, you plan to study.

When will you know that your hypotheses are clear and precise enough? Because of the way we define hypotheses, this question asks about both rationales and predictions. If a rationale you are building lets you make a number of quite different predictions that are equally plausible rather than a single, primary prediction, then your hypothesis needs further refinement by building a more complete and precise rationale. Also, if you cannot briefly describe to your colleagues a believable way to test your prediction, then you need to phrase it more clearly and precisely.

Each time you strengthen your rationales, you might need to adjust your predictions. And, each time you clarify your predictions, you might need to adjust your rationales. The cycle of going back and forth to keep your predictions and rationales tightly aligned has many payoffs down the road. Every decision you make from this point on will be in the interests of providing a transparent and convincing test of your hypotheses and explaining how the results of your test dictate specific revisions to your hypotheses. As you make these decisions (described in the succeeding chapters), you will probably return to clarify your hypotheses even further. But, you will be in a much better position, at each point, if you begin with well-informed hypotheses.

Beginning by Asking Questions to Clarify Your Interests

Instead of starting with predictions, a second path you might take devotes more time at the beginning to asking questions as you zero in on what you want to study. Some researchers suggest you start this way (e.g., Gournelos et al., 2019). Specifically, with this second path, the first statement you write to express your research interest would be a question. For example, you might ask, "Why do ninth-grade students change the way they think about linear equations after studying quadratic equations?" or "How do first graders solve simple arithmetic problems before they have been taught to add and subtract?"

The first phrasing of your question might be quite general or vague. As you think about your question and what you *really* want to know, you are likely to ask follow-up questions. These questions will almost always be more specific than your first question. The questions will also express more clearly what you want to know. So, the question "How do first graders solve simple arithmetic problems before they have been taught to add and subtract" might evolve into "Before first graders have been taught to solve arithmetic problems, what strategies do they use to solve arithmetic problems with sums and products below 20?" As you read and learn about what others already know about your questions, you will continually revise your questions toward clearer and more explicit and more precise versions that zero in on what you really want to know. The question above might become, "Before they are taught to solve arithmetic problems, what strategies do beginning first graders use to solve arithmetic problems with sums and products below 20 if they are read story problems and given physical counters to help them keep track of the quantities?"

Imagining Answers to Your Questions

If you monitor your own thinking as you ask questions, you are likely to begin forming some guesses about answers, even to the early versions of the questions. What do students learn about quadratic functions that influences changes in their proportional reasoning when dealing with linear functions? It could be that if you analyze the moments during instruction on quadratic equations that are extensions of the proportional reasoning involved in solving linear equations, there are times when students receive further experience reasoning proportionally. You might predict that these are the experiences that have a "backward transfer" effect (Hohensee, 2014).

These initial guesses about answers to your questions are your first predictions. The first predicted answers are likely to be hunches or fuzzy, vague guesses. This simply means you do not know very much yet about the question you are asking. Your first predictions, no matter how unfocused or tentative, represent the most you know at the time about the question you are asking. They help you gauge where you are in your thinking.

Shifting to the Hypothesis Formulation and Testing Path

Research questions can play an important role in the research process. They provide a succinct way of capturing your research interests and communicating them to others. When colleagues want to know about your work, they will often ask "What are your research questions?" It is good to have a ready answer.

However, research questions have limitations. They do not capture the three images of scientific inquiry presented in Chap. 1. Due, in part, to this less expansive depiction of the process, research questions do not take you very far. They do not provide a guide that leads you through the phases of conducting a study.

Consequently, when you can imagine an answer to your research question, we recommend that you move onto the hypothesis formulation and testing path. Imagining an answer to your question means you can make plausible predictions. You can now begin clarifying the reasons for your predictions and transform your early predictions into hypotheses (predictions along with rationales). We recommend you do this as soon as you have guesses about the answers to your questions because formulating, testing, and revising hypotheses offers a tool that puts you squarely on the path of scientific inquiry. It is a tool that can guide you through the *entire* process of conducting a research study.

This does not mean you are finished asking questions. Predictions are often created as answers to questions. So, we encourage you to continue asking questions to clarify what you want to know. But your target shifts from *only* asking questions to also proposing predictions for the answers and developing reasons the answers will be accurate predictions. It is by predicting answers, and explaining why you made those predictions, that you become engaged in scientific inquiry.

Cycles of Refining Questions and Predicting Answers

An example might provide a sense of how this process plays out. Suppose you are reading about Vygotsky's (1987) *zone of proximal development* (ZPD), and you realize this concept might help you understand why your high school students had trouble learning exponential functions. Maybe they were outside this zone when you tried to teach exponential functions. In order to recognize students who would benefit from instruction, you might ask, "How can I identify students who are within the ZPD around exponential functions?" What would you predict? Maybe students in this ZPD are those who already had knowledge of related functions. You could write out some reasons for this prediction, like "students who understand linear and quadratic functions are more likely to extend their knowledge to exponential functions." But what kind of data would you need to test this? What would count as "understanding"? Are linear and quadratic the functions you should assess? Even if they are, how could you tell whether students who scored well on tests of linear and quadratic functions were within the ZPD of exponential functions? How, in the end, would you measure what it means to be in this ZPD? So, asking a series of reasonable questions raised some red flags about the way your initial question was phrased, and you decide to revise it.

You set the stage for revising your question by defining ZPD as the zone within which students can solve an exponential function problem by making only one additional conceptual connection between what they already know and exponential functions. Your revised question is, "Based on students' knowledge of linear and quadratic functions, which students are within the ZPD of exponential functions?" This time you know what kind of data you need: the number of conceptual connections students need to bridge from their knowledge of related functions to exponential functions. How can you collect these data? Would you need to see into the minds of the students? Or, are there ways to test the number of conceptual connections someone makes to move from one topic to another? Do methods exist for gathering these data? You decide this is not realistic, so you now have a choice: revise the question further or move your research in a different direction.

Notice that we do not use the term *research question* for all these early versions of questions that begin clarifying for yourself what you want to study. These early versions are too vague and general to be called research questions. *In this book, we save the term research question for a question that comes near the end of the work and captures exactly what you want to study*. By the time you are ready to specify a research question, you will be thinking about your study in terms of hypotheses and tests. When your hypotheses are in final form and include clear predictions about what you will find, it will be easy to state the research questions that accompany your predictions.

To reiterate one of the key points of this chapter: hypotheses carry much more information than research questions. Using our definition, hypotheses include predictions about what the answer might be to the question plus reasons for why you think so. Unlike research questions, hypotheses capture all three images of scientific inquiry presented in Chap. 1 (planning, observing and explaining, and revising one's thinking). *Your hypotheses represent the most you know, at the moment, about your research topic.* The same cannot be said for research questions.

Beginning with a Research Problem

When you wrote answers to the six questions at the end of Part I of this chapter, you might have identified a research interest by stating it as a problem. This is the third path you might take to begin your research. Perhaps your description of your problem might look something like this: "When I tried to teach my middle school students by presenting them with a challenging problem without showing them how to solve similar problems, they didn't exert much effort trying to find a solution but instead waited for me to show them how to solve the problem." You do not have a specific question in mind, and you do not have an idea for why the problem exists, so you do not have a prediction about how to solve it. Writing a statement of this problem as clearly as possible could be the first step in your research journey.

As you think more about this problem, it will feel natural to ask questions about it. For example, why did some students show more initiative than others? What could I have done to get them started? How could I have encouraged the students to keep trying without giving away the solution? You are now on the path of asking questions—not research questions yet, but questions that are helping you focus your interest.

As you continue to think about these questions, reflect on your own experience, and read what others know about this problem, you will likely develop some guesses about the answers to the questions. They might be somewhat vague answers, and you might not have lots of confidence they are correct, but they are guesses that you can turn into predictions. Now you are on the hypothesis-formulation-and-testing path. This means you are on the path of asking yourself why you believe the predictions are correct, developing rationales for the predictions, asking what kinds of empirical observations would test your predictions, and refining your rationales and predictions as you read the literature and talk with colleagues.

A simple diagram that summarizes the three paths we have described is shown in Fig. 2.1. Each row of arrows represents one pathway for formulating an informed hypothesis. The dotted arrows in the first two rows represent parts of the pathways that a researcher may have implicitly travelled through already (without an intent to form a prediction) but that ultimately inform the researcher's development of a question or prediction.

Part III. One Researcher's Experience Launching a Scientific Inquiry

Martha was in her third year of her doctoral program and beginning to identify a topic for her dissertation. Based on (a) her experience as a high school mathematics teacher and a curriculum supervisor, (b) the reading she has done to this point, and (c) her conversations with her colleagues, she has developed an interest in what kinds of professional development experiences (let's call them learning opportunities [LOs] for teachers) are most effective. Where does she go from here?

Exercise 2.2
Before you continue reading, please write down some suggestions for Martha about where she should start.

A natural thing for Martha to do at this point is to ask herself some additional questions, questions that specify further what she wants to learn: What kinds of LOs do most teachers experience? How do these experiences change teachers' practices and beliefs? Are some LOs more effective than others? What makes them more effective?

To focus her questions and decide what she really wants to know, she continues reading but now targets her reading toward everything she can find that suggests possible answers to these questions. She also talks with her colleagues to get more ideas about possible answers to these or related questions. Over several weeks or months, she finds herself being drawn to questions about what makes LOs effective, especially for helping teachers teach more conceptually. She zeroes in on the question, "What makes LOs for teachers effective for improving their teaching for conceptual understanding?"

This question is more focused than her first questions, but it is still too general for Martha to define a research study. How does she know it is too general? She uses two criteria. First, she notices that the predictions she makes about the answers to the question are all over the place; they are not constrained by the reasons she has assembled for her predictions. One prediction is that LOs are more effective when they help teachers learn content. Martha makes this guess because previous research suggests that effective LOs for teachers include attention to content. But this rationale allows lots of different predictions. For example, LOs are more effective when they focus on the content teachers will teach; LOs are more effective when they focus on content beyond what teachers will teach so teachers see how their instruction fits with what their students will encounter later; and LOs are more effective when they are tailored to the level of content knowledge participants have when they begin the LOs. The rationale she can provide at this point does not point to a particular prediction.

A second measure Martha uses to decide her question is too general is that the predictions she can make regarding the answers seem very difficult to test. How could she test, for example, whether LOs should focus on content beyond what teachers will teach? What does "content beyond what teachers teach" mean? How could you tell whether teachers use their new knowledge of later content to inform their teaching?

Before anticipating what Martha's next question might be, it is important to pause and recognize how *predicting* the answers to her questions moved Martha into a new phase in the research process. As she makes predictions, works out the reasons for them, and imagines how she might test them, she is immersed in scientific inquiry. This intellectual work is the main engine that drives the research process. Also notice that revisions in the questions asked, the predictions made, and the rationales built represent the *updated thinking* (Chap. 1) that occurs as Martha continues to define her study.

Based on all these considerations and her continued reading, Martha revises the question again. The question now reads, "Do LOs that engage middle school mathematics teachers in studying mathematics content help teachers teach this same content with more of a conceptual emphasis?" Although she feels like the question is more specific, she realizes that the answer to the question is either "yes" or "no." This, by itself, is a red flag. Answers of "yes" or "no" would not contribute much to understanding the relationships between these LOs for teachers and changes in their teaching. Recall from Chap. 1 that *understanding* how things work, *explaining why* things work, is the goal of scientific inquiry.

Martha continues by trying to understand why she believes the answer is "yes." When she tries to write out reasons for predicting "yes," she realizes that her prediction depends on a variety of factors. If teachers already have deep knowledge of the content, the LOs might not affect them as much as other teachers. If the LOs do not help teachers develop their own conceptual understanding, they are not likely to change their teaching. By trying to build the rationale for her prediction—thus formulating a hypothesis—Martha realizes that the question still is not precise and clear enough.

Martha uses what she learned when developing the rationale and rephrases the question as follows: "*Under what conditions* do LOs that engage middle school mathematics teachers in studying mathematics content help teachers teach this same content with more of a conceptual emphasis?" Through several additional cycles of thinking through the rationale for her predictions and how she might test them, Martha specifies her question even further: "Under what conditions do middle school teachers who lack conceptual knowledge of linear functions benefit from LOs that engage them in conceptual learning of linear functions as assessed by changes in their teaching toward a more conceptual emphasis on linear functions?"

Each version of Martha's question has become more specific. This has occurred as she has (a) identified a starting condition for the teachers—they lack conceptual knowledge of linear functions, (b) specified the mathematics content as linear functions, and (c) included a condition or purpose of the LO—it is aimed at conceptual learning.

Because of the way Martha's question is now phrased, her predictions will require thinking about the conditions that could influence what teachers learn from the LOs and how this learning could affect their teaching. She might predict that if teachers engaged in LOs that extended over multiple sessions, they would develop deeper understanding which would, in turn, prompt changes in their teaching. Or she might predict that if the LOs included examples of how their conceptual learning could translate into different instructional activities for their students, teachers would be more likely to change their teaching. Reasons for these predictions would likely come from research about the effects of professional development on teachers' practice.

As Martha thinks about testing her predictions, she realizes it will probably be easier to measure the conditions under which teachers are learning than the changes in the conceptual emphasis in their instruction. She makes a note to continue searching the literature for ways to measure the "conceptualness" of teaching.

As she refines her predictions and expresses her reasons for the predictions, she formulates a hypothesis (in this case several hypotheses) that will guide her research. As she makes predictions and develops the rationales for these predictions, she will probably continue revising her question. She might decide, for example, that she is not interested in studying the condition of different numbers of LO sessions and so decides to remove this condition from consideration by including in her question something like ". . . over five 2-hour sessions . . ."

At this point, Martha has developed a research question, articulated a number of predictions, and developed rationales for them. Her current question is: "Under what conditions do middle school teachers who lack conceptual knowledge of linear functions benefit from five 2-hour LO sessions that engage them in conceptual learning of linear functions as assessed by changes in their teaching toward a more conceptual emphasis on linear functions?" Her hypothesis is:

- **Prediction:** Participating teachers will show changes in their teaching with a greater emphasis on conceptual understanding, with larger changes on linear function topics directly addressed in the LOs than on other topics.
- **Brief Description of Rationale:** (1) Past research has shown correlations between teachers' specific mathematics knowledge of a topic and the quality of their teaching of that topic. This does not mean an increase in knowledge *causes* higher quality teaching but it allows for that possibility. (2) Transfer is usually difficult for teachers, but the examples developed during the LO sessions will help them use what they learned to teach for conceptual understanding. This is because the examples developed during the LO sessions are much like those that will be used by the teachers. So larger changes will be found when teachers are teaching the linear function topics addressed in the LOs.

Notice it is more straightforward to imagine how Martha could test this prediction because it is more precise than previous predictions. Notice also that by asking how to test a particular prediction, Martha will be faced with a decision about whether testing this prediction will tell her something she wants to learn. If not, she can return to the research question and consider how to specify it further and, perhaps, constrain further the conditions that could affect the data.

As Martha formulates her hypotheses and goes through multiple cycles of refining her question(s), articulating her predictions, and developing her rationales, she is constantly building the *theoretical framework* for her study. Because the theoretical framework is the topic for Chap. 3, we will pause here and pick up Martha's story in the next chapter. Spoiler alert: Martha's experience contains some surprising twists and turns.

Before leaving Martha, however, we point out two aspects of the process in which she has been engaged. First, it can be useful to think about the process as identifying (1) the *variables* targeted in her predictions, (2) the *mechanisms* she believes explain the relationships among the variables, and (3) the *definitions* of all the terms that are special to her educational problem. By variables, we mean things that can be measured and, when measured, can take on different values. In Martha's case, the variables are the conceptualness of teaching and the content topics addressed in the LOs. The mechanisms are cognitive processes that enable teachers to see the relevance of what they learn in PD to their own teaching and that enable the transfer of learning from one setting to another. Definitions are the precise descriptions of how the important ideas relevant to the research are conceptualized. In Martha's case, definitions must be provided for terms like conceptual understanding, linear functions, LOs, each of the topics related to linear functions, instructional setting, and knowledge transfer.

A second aspect of the process is a practice that Martha acquired as part of her graduate program, a practice that can go unnoticed. Martha writes out, in full sentences, her thinking as she wrestles with her research question, her predictions of the answers, and the rationales for her predictions. Writing is a tool for organizing thinking and we recommend you use it throughout the scientific inquiry process. We say more about this at the end of the chapter.

Here are the questions Martha wrote as she developed a clearer sense of what question she wanted to answer and what answer she predicted. The list shows the increasing refinement that occurred as she continued to read, think, talk, and write.

Early questions: What kinds of LOs do most teachers experience? How do these experiences change teachers' practices and beliefs? Are some LOs more effective than others? What makes them more effective?

First focused question: What makes LOs for teachers effective for improving their teaching for conceptual understanding?

Question after trying to predict the answer and imagining how to test the prediction: Do LOs that engage middle school mathematics teachers in studying mathematics content help teachers teach this same content with more of a conceptual emphasis?

Question after developing an initial rationale for her prediction: *Under what conditions* do LOs that engage middle school mathematics teachers in studying mathematics content help teachers teach this same content with more of a conceptual emphasis?

Question after developing a more precise prediction and richer rationale: Under what conditions do middle school teachers who lack conceptual knowledge of linear functions benefit from five 2-hour LO sessions that engage them in conceptual learning of linear functions as assessed by changes in their teaching toward a more conceptual emphasis on linear functions?

Part IV. An Illustrative Dialogue

The story of Martha described the major steps she took to refine her thinking. However, there is a lot of work that went on behind the scenes that wasn't part of the story. For example, Martha had conversations with fellow students and professors that sharpened her thinking. What do these conversations look like? Because they are such an important part of the inquiry process, it will be helpful to "listen in" on the kinds of conversations that students might have with their advisors.

Here is a dialogue between a beginning student, Sam (S), and their advisor, Dr. Avery (A). They are meeting to discuss data Sam collected for a course project. The dialogue below is happening very early on in Sam's conceptualization of the study, prior even to systematic reading of the literature.

S: Thanks for meeting with me today. As you know, I was able to collect some data for a course project a few weeks ago, but I'm having trouble analyzing the data, so I need your help. Let me try to explain the problem. As you know, I wanted to understand what middle-school teachers do to promote girls' achievement in a mathematics class. I conducted four observations in each of three teachers' classrooms. I also interviewed each teacher once about the four lessons I observed, and I interviewed two girls from each of the teachers' classes. Obviously, I have a ton of data. But when I look at all these data, I don't really know what I learned about my topic. When I was observing the teachers, I thought I might have observed some ways the teachers were promoting girls' achievement, but then I wasn't sure how to interpret my data. I didn't know if the things I was observing were actually promoting girls' achievement.

A: What were some of your observations?

S: Well, in a couple of my classroom observations, teachers called on girls to give an answer, even when the girls didn't have their hands up. I thought that this might be a way that teachers were promoting the girls' achievement. But then the girls didn't say anything about that when I interviewed them and also the teachers didn't do it in every class. So, it's hard to know what effect, if any, this might have had on their learning or their motivation to learn. I didn't want to ask the girls during the interview specifically about the teacher calling on them, and without the girls bringing it up themselves, I didn't know if it had any effect.

A: Well, why didn't you want to ask the girls about being called on?

S: Because I wanted to leave it as open as possible; I didn't want to influence what they were going to say. I didn't want to put words in their mouths. I wanted to know what *they* thought the teacher was doing that promoted their mathematical achievement and so I only asked the girls general questions, like "Do you think the teacher does things to promote girls' mathematical achievement?" and "Can you describe specific experiences you have had that you believe do and do not promote your mathematical achievement?"

A: So then, how did they answer those general questions?

S: Well, with very general answers, such as that the teacher knows their names, offers review sessions, grades their homework fairly, gives them opportunities to earn extra credit, lets them ask questions, and always answers their questions. Nothing specific that helps me know what teaching actions specifically target girls' mathematics achievement.

A: OK. Any ideas about what you might do next?

S: Well, I remember that when I was planning this data collection for my course, you suggested I might want to be more targeted and specific about what I was looking for. I can see now that more targeted questions would have made my data more interpretable in terms of connecting teaching actions to the mathematical achievement of girls. But I just didn't want to influence what the girls would say.

A: Yes, I remember when you were planning your course project, you wanted to keep it open. You didn't want to miss out on discovering something new and interesting. What do you think now about this issue?

S: Well, I still don't want to put words in their mouths. I want to know what *they* think. But I see that if I ask really open questions, I have no guarantee they will talk about what I want them to talk about. I guess I still like the idea of an open study, but I see that it's a risky approach. Leaving the questions too open meant I didn't constrain their responses and there were too many ways they could interpret and answer the questions. And there are too many ways I could interpret their responses.

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By this point in the dialogue, Sam has realized that open data (i.e., data not testing a specific prediction) is difficult to interpret. In the next part, Dr. Avery explains why collecting open data was not helping Sam achieve goals for her study that had motivated collecting open data in the first place.

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A: Yes, I totally agree. Even for an experienced researcher, it can be difficult to make sense of this kind of open, messy data. However, if you design a study with a more specific focus, you can create questions for participants that are more targeted because you will be interested in their answers to these specific questions. Let's reflect back on your data collection. What can you learn from it for the future?

S: When I think about it now, I realize that I didn't think about the distinction between all the different constructs at play in my study, and I didn't choose which one I was focusing on. One construct was the teaching moves that teachers think could be promoting achievement. Another is what teachers deliberately do to promote girls' mathematics achievement, if anything. Another was the teaching moves that actually do support girls' mathematics achievement. Another was what teachers were doing that supported *girls'* mathematics achievement versus the mathematics achievement of all students. Another was students' perception of what their teacher was doing to promote girls' mathematics achievement. I now see that any one of these constructs could have been the focus of a study and that I didn't really decide which of these was the focus of my course project prior to collecting data.

A: So, since you told me that the topic of this course project is probably what you'll eventually want to study for your dissertation, which of these constructs are you most interested in?

S: I think I'm more interested in the teacher moves that teachers deliberately do to promote girls' achievement. But I'm still worried about asking teachers directly and getting too specific about what they do because I don't want to bias what they will say. And I chose qualitative methods and an exploratory design because I thought it would allow for a more open approach, an approach that helps me see what's going on and that doesn't bias or predetermine the results.

A: Well, it seems to me you are conflating three issues. One issue is how to conduct an unbiased study. Another issue is how specific to make your study. And the third issue is whether or not to choose an exploratory or qualitative study design. Those three issues are not the same. For example, designing a study that's more open or more exploratory is not how researchers make studies fair and unbiased. In fact, it would be quite easy to create an *open* study that is biased. For example, you could ask very open questions and then interpret the responses in a way that unintentionally, and even unknowingly, aligns with what you were hoping the findings would say. Actually, you could argue that by adding more specificity and narrowing your focus, you're creating constraints that prevent bias. The same goes for an exploratory or qualitative study; they can be biased or unbiased. So, let's talk about what is meant by getting more specific. Within your new focus on what teachers deliberately do, there are many things that would be interesting to look at, such as teacher moves that address math anxiety, moves that allow girls to answer questions more frequently, moves that are specifically fitted to student thinking about specific mathematical content, and so on. What are one or two things that are most interesting to you? One way to answer this question is by thinking back to where your interest in this topic began.

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In the preceding part of the dialogue, Dr. Avery explained how the goals Sam had for their study were not being met with open data. In the next part, Sam begins to articulate a prediction, which Sam and Dr. Avery then sharpen.

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S: Actually, I became interested in this topic because of an experience I had in college when I was in a class of mostly girls. During whole class discussions, we were supposed to critically evaluate each other's mathematical thinking, but we were too polite to do that. Instead, we just praised each other's work. But it was so different in our small groups. It seemed easier to critique each other's thinking and to push each other to better solutions in small groups. I began wondering how to get girls to be more critical of each other's thinking in a whole class discussion in order to push *everyone's* thinking.

A: Okay, this is great information. Why not use this idea to zoom-in on a more manageable and interpretable study? You could look specifically at how teachers support girls in critically evaluating each other's thinking during whole class discussions. That would be a much more targeted and specific topic. Do you have predictions about what teachers could do in that situation, keeping in mind that you are looking specifically at girls' mathematical achievement, not students in general?

S: Well, what I noticed was that small groups provided more social and emotional support for girls, whereas the whole class discussion did not provide that same support. The girls felt more comfortable critiquing each other's thinking in small groups. **So, I guess I predict that when the social and emotional supports that are present in small groups are extended to the whole class discussion, girls would be more willing to evaluate each other's mathematical thinking critically during whole class discussion**. I guess ultimately, I'd like to know how the whole class discussion could be used to enhance, rather than undermine, the social and emotional support that is present in the small groups.

A: Okay, then where would you start? Would you start with a study of what the teachers say they will do during whole class discussion and then observe if that happens during whole class discussion?

S: But part of my prediction also involves the small groups. So, I'd also like to include small groups in my study if possible. If I focus on whole groups, I won't be exploring what I am interested in. My interest is broader than just the whole class discussion.

A: That makes sense, but there are many different things you could look at as part of your prediction, more than you can do in one study. For instance, if your prediction is that **when the social and emotional supports that are present in small groups are extended to whole class discussions, girls would be more willing to evaluate each other's mathematical thinking critically during whole class discussions**, then you could ask the following questions: What are the social and emotional supports that are present in small groups?; In which small groups do they exist?; Is it groups that are made up only of girls?; Does every small group do this, and for groups that do this, when do these supports get created?; What kinds of small group activities that teachers ask them to work on are associated with these supports?; Do the same social and emotional supports that apply to small groups even apply to whole group discussion?

S: All your questions make me realize that my prediction about extending social and emotional supports to whole class discussions first requires me to have a better understanding of the social and emotional supports that exist in small groups. In fact, I first need to find out whether those supports commonly exist in small groups or is that just my experience working in small groups. So, I think I will first have to figure out what small groups do to support each other and then, in a later study, I could ask a teacher to implement those supports during whole class discussions and find out how you can do that. Yeah, now I'm seeing that.

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The previous part of the dialogue illustrates how continuing to ask questions about one's initial prediction is a good way to make it more and more precise (and researchable). In the next part, we see how developing a precise prediction has the added benefit of setting the researcher up for future studies.

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A: Yes, I agree that for your first study, you should probably look at small groups. In other words, you should focus on only a part of your prediction for now, namely the part that says **there are social and emotional supports in small groups that support girls in critiquing each other's thinking**. That begins to sharpen the focus of your prediction, but you'll want to continue to refine it. For example, right now, the question that this prediction leads to is a question with a yes or no answer, but what you've said so far suggests to me that you are looking for more than that.

S: Yes, I want to know more than just whether there are supports. I'd like to know what kinds. That's why I wanted to do a qualitative study.

A: Okay, this aligns more with my thinking about research as being prediction driven. It's about collecting data that would help you revise your existing predictions into better ones. What I mean is that you would focus on collecting data that would allow you to refine your prediction, make it more nuanced, and go beyond what is already known. Does that make sense, and if so, what would that look like for your prediction?

S: Oh yes, I like that. I guess that would mean that, based on the data I collect for this next study, I could develop a more refined prediction that, for example, more specifically identifies and differentiates between different kinds of social and emotional supports that are present in small groups, or maybe that identifies the kinds of small groups that they occur in, or that predicts when and how frequently or infrequently they occur, or about the features of the small group tasks in which they occur, etc. I now realize that, although I chose qualitative research to make my study be more open, really the reason qualitative research fits my purposes is because it will allow me to explore fine-grained aspects of social and emotional supports that may exist for girls in small groups.

A: Yes, exactly! And then, based on the data you collect, you can include in your revised prediction those new fine-grained aspects. Furthermore, you will have a story to tell about your study in your written report, namely the story about your evolving prediction. In other words, your written report can largely tell how you filled out and refined your prediction as you learned more from carrying out the study. And even though you might not use them right away, you are also going to be able to develop new predictions that you would not have even thought of about social and emotional supports in small groups and your aim of extending them to whole-class discussions, had you not done this study. That will set you up to follow up on those new predictions in future studies. For example, you might have more refined ideas after you collect the data about the goals for critiquing student thinking in small groups versus the goals for critiquing student thinking during whole class discussion. You might even begin to think that some of the social and emotional supports you observe are not even replicable or even applicable to or appropriate for whole-class discussions, because the supports play different roles in different contexts. So, to summarize what I'm saying, what you look at in this study, even though it will be very focused, sets you up for a research program that will allow you to more fully investigate your broader interest in this topic, where each new study builds on your prior body of work. That's why it is so important to be explicit about the best place to start this research, so that you can build on it.

S: I see what you are saying. We started this conversation talking about my course project data. What I think I should have done was figure out explicitly what I needed to learn with that study with the intention of then taking what I learned and using it as the basis for the next study. I didn't do that, and so I didn't collect data that pushed forward my thinking in ways that would guide my next study. It would be as if I was starting over with my next study.

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Sam and Dr. Avery have just explored how specifying a prediction reveals additional complexities that could become fodder for developing a systematic research program. Next, we watch Sam beginning to recognize the level of specificity required for a prediction to be testable.

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A: One thing that would have really helped would have been if you had had a specific prediction going into your data collection for your course project.

S: Well, I didn't really have much of an explicit prediction in mind when I designed my methods.

A: Think back, you must have had some kind of prediction, even if it was implicit.

S: Well, yes, I guess I was predicting that teachers would enact moves that supported girls' mathematical achievement. And I observed classrooms to identify those teacher moves, I interviewed teachers to ask them about the moves I observed, and I interviewed students to see if they mentioned those moves as promoting their mathematical achievement. The goal of my course project was to identify teacher moves that support girls' mathematical achievement. And my specific research question was: What teacher moves support girls' mathematical achievement?

A: So, really you were asking the teacher and students to show and tell you what those moves are and the effects of those moves, as a result putting the onus on your participants to provide the answers to your research question for you. I have an idea, let's try a thought experiment. You come up with data collection methods for testing the prediction that **there are social and emotional supports in small groups that support girls in critiquing each other's thinking** that still puts the onus on the participants. And then I'll see if I can think of data collection methods that would not put the onus on the participants.

S: Hmm, well. .. I guess I could simply interview girls who participated in small groups and ask them "are there social and emotional supports that you use in small groups that support your group in critiquing each other's thinking and if so, what are they?" In that case, I would be putting the onus on them to be aware of the social dynamics of small groups and to have thought about these constructs as much as I have. Okay now can you continue the thought experiment? What might the data collection methods look like if I didn't put the onus on the participants?

A: First, I would pick a setting in which it was only girls at this point to reduce the number of variables. Then, personally I would want to observe a lot of groups of girls interacting in groups around tasks. I would be looking for instances when the conversation about students' ideas was shut down and instances when the conversation about students' ideas involved critiquing of ideas and building on each other's thinking. I would also look at what happened just before and during those instances, such as: did the student continue to talk after their thinking was critiqued, did other students do anything to encourage the student to build on their own thinking (i.e., constructive criticism) or how did they support or shut down continued participation. In fact, now that I think about it, "critiquing each other's thinking" can be defined in a number of different ways. I could mean just commenting on someone's thinking, judging correctness and incorrectness, constructive criticism that moves the thinking forward, etc. If you put the onus on the participants to answer your research question, you are stuck with their definition, and they won't have thought about this very much, if at all.

S: I think that what you are also saying is that my definitions would affect my data collection. If I think that critiquing each other's thinking means that the group moves their thinking forward toward more valid and complete mathematical solutions, then I'm going to focus on different moves than if I define it another way, such as just making a comment on each other's thinking and making each other feel comfortable enough to keep participating. In fact, am I going to look at individual instances of critiquing or look at entire sequences in which the critiquing leads to a goal? This seems like a unit of analysis question, and I would need to develop a more nuanced prediction that would make explicit what that unit of analysis is.

A: I agree, your definition of "critiquing each other's thinking" could entirely change what you are predicting. One prediction could be based on defining critiquing as a one-shot event in which someone makes one comment on another person's thinking. In this case the prediction would be that **there are social and emotional supports in small groups that support girls in making an evaluative comment on another student's thinking.** Another prediction could be based on defining critiquing as a back-and-forth process in which the thinking gets built on and refined. In that case, the prediction would be something like that **there are social and emotional supports in small groups that support girls in critiquing each other's thinking in ways that do not shut down the conversation but that lead to sustained conver-**

sations that move each other toward more valid and complete solutions.

S: Well, I think I am more interested in the second prediction because it is more compatible with my long-term interests, which are that I'm interested in extending small group supports to whole class discussions. The second prediction is more appropriate for eventually looking at girls in whole class discussion. During whole class discussion, the teacher tries to get a sustained conversation going that moves the students' thinking forward. So, if I learn about small group supports that **lead to sustained conversations that move each other toward more valid and complete solutions**, those supports might transfer to whole class discussions.

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In the previous part of the dialogue, Dr. Avery and Sam showed how narrowing down a prediction to one that is testable requires making numerous important decisions, including how to define the constructs referred to in the prediction. In the final part of the dialogue, Dr. Avery and Sam begin to outline the reading Sam will have to do to develop a rationale for the specific prediction.

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A: Do you see how your prediction and definitions are getting more and more specific? You now need to read extensively to further refine your prediction.

S: Well, I should probably read about micro dynamics of small group interactions, anything about interactions in small groups, and what is already known about small group interactions that support sustained conversations that move students' thinking toward more valid and complete solutions. I guess I could also look at research on whole-class discussion methods that support sustained conversations that move the class to more mathematically valid and complete solutions, because it might give me ideas for what to look for in the small groups. I might also need to focus on research about how learners develop understandings about a particular subject matter so that I know what "more valid and complete solutions" look like. I also need to read about social and emotional supports but focus on how they support students cognitively, rather than in other ways.

A: Sounds good, let's get together after you have processed some of this literature and we can talk about refining your prediction based on what you read and also the methods that will best suit testing that prediction.

S: Great! Thanks for meeting with me. I feel like I have a much better set of tools that push my own thinking forward and allow me to target something specific that will lead to more interpretable data.

Part V. Is It Always Possible to Formulate Hypotheses?

In Chap. 1, we noted you are likely to read that research does not require formulating hypotheses. Some sources describe doing research without making predictions and developing rationales for these predictions. Some researchers say you cannot always make predictions—you do not know enough about the situation. In fact, some argue for the value of *not* making predictions (e.g., Glaser & Holton, 2004; Merton, 1968; Nemirovsky, 2011). These are important points of view, so we will devote this section to discussing them.

Can You Always Predict What You Will Find?

One reason some researchers say you do not need to make predictions is that it can be difficult to imagine what you will find. This argument comes up most often for descriptive studies. Suppose you want to describe the nature of a situation you do not know much about. Can you still make a prediction about what you will find? We believe that, although you do not know exactly what you will find, you probably have a hunch or, at a minimum, a very fuzzy idea. It would be unusual to ask a question about a situation you want to know about without at least a fuzzy inkling of what you might find. The original question just would not occur to you. We acknowledge you might have only a vague idea of what you will find and you might not have much confidence in your prediction. However, we expect if you monitor your own thinking you will discover you have developed a suspicion along the way, regardless how vague the suspicion might be. Through the cyclic process we discussed above, that suspicion or hunch gradually evolves and turns into a prediction.

The Benefits of Making Predictions Even When They Are Wrong: An Example from the 1970s

One of us was a graduate student at the University of Wisconsin in the late 1970s, assigned as a research assistant to a project that was investigating young children's thinking about simple arithmetic. A new curriculum was being written, and the developers wanted to know how to introduce the earliest concepts and skills to kindergarten and first-grade children. The directors of the project did not know what to expect because, at the time, there was little research on five- and six-year-olds' pre-instruction strategies for adding and subtracting.

After consulting what literature was available, talking with teachers, analyzing the nature of different types of addition and subtraction problems, and debating with each other, the research team formulated some hypotheses about children's performance. Following the usual assumptions at the time and recognizing the new curriculum would introduce the concepts, the researchers predicted that, before instruction, most children would not be able to solve the problems. Based on the rationale that some young children did not yet recognize the simple form for written problems (e.g., 5 + 3 = ___), the researchers predicted that the best chance for success would be to read problems as stories (e.g., Jesse had 5 apples and then found 3 more. How many does she have now?). They reasoned that, even though children would have difficulty on all the problems, some story problems would be easier because the semantic structure is easier to follow. For example, they predicted the above story about adding 3 apples to 5 would be easier than a problem like, "Jesse had some apples in the refrigerator. She put in 2 more and now has 6. How many were in the refrigerator at the beginning?" Based on the rationale that children would need to count to solve the problems and that it can be difficult to keep track of the numbers, they predicted children would be more successful if they were given counters. Finally, accepting the common reasoning that larger numbers are more difficult than smaller numbers, they predicted children would be more successful if all the numbers in a problem were below 10.

Although these predictions were not very precise and the rationales were not strongly convincing, these hypotheses prompted the researchers to design the study to test their predictions. This meant they would collect data by presenting a variety of problems under a variety of conditions. Because the goal was to describe children's thinking, problems were presented to students in individual interviews. Problems with different semantic structures were included, counters were available for some problems but not others, and some problems had sums to 9 whereas others had sums to 20 or more.

The punchline of this story is that gathering data under these conditions, prompted by the predictions, made all the difference in what the researchers learned. Contrary to predictions, children could solve addition and subtraction problems before instruction. Counters were important because almost all the solution strategies were based on counting which meant that memory was an issue because many strategies require counting in two ways simultaneously. For example, subtracting 4 from 7 was usually solved by counting down from 7 while counting up from 1 to 4 to keep track of counting down. Because children acted out the stories with their counters, the semantic structure of the story was also important. Stories that were easier to read and write were also easier to solve.

To make a very long story very short, other researchers were, at about the same time, reporting similar results about children's pre-instruction arithmetic capabilities. A clear pattern emerged regarding the relative difficulty of different problem types (semantic structures) and the strategies children used to solve each type. As the data were replicated, the researchers recognized that kindergarten and first-grade teachers could make good use of this information when they introduced simple arithmetic. This is how *Cognitively Guided Instruction* (CGI) was born (Carpenter et al., 1989; Fennema et al., 1996).

To reiterate, the point of this example is that the study conducted to describe children's thinking would have looked quite different if the researchers had made no predictions. They would have had no reason to choose the particular problems and present them under different conditions. The fact that some of the predictions were completely wrong is not the point. The predictions created the conditions under which the predictions were tested which, in turn, created learning opportunities for the researchers that would not have existed without the predictions. The lesson is that even research that aims to simply describe a phenomenon can benefit from hypotheses. As signaled in Chap. 1, this also serves as another example of "failing productively."

Suggestions for What to Do When You Do Not Have Predictions

There likely are exceptions to our claim about being able to make a prediction about what you will find. For example, there could be rare cases where researchers truly have no idea what they will find and can come up with no predictions and even no hunches. And, no research has been reported on related phenomena that would offer some guidance. If you find yourself in this position, we suggest one of three approaches: revise your question, conduct a pilot study, or choose another question.

Because there are many advantages to making predictions explicit and then writing out the reasons for these predictions, one approach is to adjust your question just enough to allow you to make a prediction. Perhaps you can build on descriptions that other researchers have provided for related situations and consider how you can extend this work. Building on previous descriptions will enable you to make predictions about the situation you want to describe.

A second approach is to conduct a small pilot study or, better, a series of small pilot studies to develop some preliminary ideas of what you might find. If you can identify a small sample of participants who are similar to those in your study, you can try out at least some of your research plans to help make and refine your predictions. As we detail later, you can also use pilot studies to check whether key aspects of your methods (e.g., tasks, interview questions, data collection methods) work as you expect.

A third approach is to return to your list of interests and choose one that has been studied previously. Sometimes this is the wisest choice. It is very difficult for beginning researchers to conduct research in brand-new areas where no hunches or predictions are possible. In addition, the contributions of this research can be limited. Recall the earlier story about one of us "failing productively" by completing a dissertation in a somewhat new area. If, after an exhaustive search, you find that no one has investigated the phenomenon in which you are interested or even related phenomena, it can be best to move in a different direction. You will read recommendations in other sources to find a "gap" in the research and develop a study to "fill the gap." This can be helpful advice if the gap is very small. However, if the gap is large, too large to predict what you might find, the study will present severe challenges. It will be more productive to extend work that has already been done than to launch into an entirely new area.

Should You Always Try to Predict What You Will Find?

In short, our answer to the question in the heading is "yes." But this calls for further explanation.

Suppose you want to observe a second-grade classroom in order to investigate how students talk about adding and subtracting whole numbers. You might think, "I don't want to bias my thinking; I want to be completely open to what I see in the classroom." Sam shared a similar point of view at the beginning of the dialogue: "I wanted to leave it as open as possible; I didn't want to influence what they were going to say." Some researchers say that beginning your research study by making predictions is inappropriate precisely because it will bias your observations and results. The argument is that by bringing a set of preconceptions, you will confirm what you expected to find and be blind to other observations and outcomes. The following quote illustrates this view: "The first step in gaining theoretical sensitivity is to enter the research setting with as few predetermined ideas as possible—especially logically deducted, a priori hypotheses. In this posture, the analyst is able to remain sensitive to the data by being able to record events and detect happenings without first having them filtered through and squared with pre-existing hypotheses and biases" (Glaser, 1978, pp. 2–3).

We take a different point of view. In fact, we believe there are several compelling reasons for making your predictions explicit.

Making Your Predictions Explicit Increases Your Chances of Productive Observations

Because your predictions are an extension of what is already known, they prepare you to identify more nuanced relationships that can advance our understanding of a phenomenon. For example, rather than simply noticing, in a general sense, that students talking about addition and subtraction leads them to better understandings, you might, based on your prediction, make the specific observation that talking about addition and subtraction in a particular way helps students to think more deeply about a particular concept related to addition and subtraction. Going into a study without predictions can bring less sensitivity rather than more to the study of a phenomenon. Drawing on knowledge about related phenomena by reading the literature and conducting pilot studies allows you to be much more sensitive and your observations to be more productive.

Making Your Predictions Explicit Allows You to Guard Against Biases

Some genres and methods of educational research are, in fact, rooted in philosophical traditions (e.g., Husserl, 1929/1973) that explicitly call for researchers to temporarily "bracket" or set aside existing theory as well as their prior knowledge and experience to better enter into the experience of the participants in the research. However, this does not mean ignoring one's own knowledge and experience or turning a blind eye to what has been learned by others. Much more than the simplistic image of emptying one's mind of preconceptions and implicit biases (arguably an impossible feat to begin with), the goal is to be as reflective as possible about one's prior knowledge and conceptions and as transparent as possible about how they may guide observations and shape interpretations (Levitt et al., 2018).

We believe it is better to be honest about the predictions you are almost sure to have because then you can deliberately plan to minimize the chances they will influence what you find and how you interpret your results. For starters, it is important to recognize that acknowledging you have some guesses about what you will find does not make them more influential. Because you are likely to have them anyway, we recommend being explicit about what they are. It is easier to deal with biases that are explicit than those that lurk in the background and are not acknowledged.

What do we mean by "deal with biases"? Some journals require you to include a statement about your "positionality" with respect to the participants in your study and the observations you are making to gather data. Formulating clear hypotheses is, in our view, a direct response to this request. The reasons for your predictions are your explicit statements about your positionality. Often there are methodological strategies you can use to protect the study from undue influences of bias. In other words, making your vague predictions explicit can help you design your study so you minimize the bias of your findings.

Making Your Predictions Explicit Can Help You See What You Did Not Predict

Making your predictions explicit does not need to blind you to what is different than expected. It does not need to force you to see only what you want to see. Instead, it can actually increase your sensitivity to noticing features of the situation that are surprising, features you did *not* predict. Results can stand out when you did not expect to see them.

In contrast, not bringing your biases to consciousness might subtly shift your attention away from these unexpected results in ways that you are not aware of. This path can lead to claiming no biases and no unexpected findings without being conscious of them. You cannot observe everything, and some things inevitably will be overlooked. If you have predicted what you will see, you can design your study so that the unexpected results become more salient rather than less.

Returning to the example of observing a second-grade classroom, we note that the field already knows a great deal about how students talk about addition and subtraction. Being cognizant of what others have observed allows you to enter the classroom with some clear predictions about what will happen. The rationales for these predictions are based on all the related knowledge you have before stepping into the classroom, and the predictions and rationales help you to better deal with what you see. This is partly because you are likely to be surprised by the things you did not anticipate. There is almost always something that will surprise you because your predictions will almost always be incomplete or too general. This sensitivity to the unanticipated—the sense of surprise that sparks your curiosity—is an indication of your openness to the phenomenon you are studying.

Making Your Predictions Explicit Allows You to Plan in Advance

Recall from Chap. 1 the descriptor of scientific inquiry: "Experience carefully planned in advance." If you make no predictions about what might happen, it is very difficult, if not impossible, to plan your study in advance. Again, you cannot observe everything, so you must make decisions about what you will observe. What kind of data will you plan to collect? Why would you collect these data instead of others? If you have no idea what to expect, on what basis will you make these consequential decisions? Even if your predictions are vague and your rationales for the predictions are a bit shaky, at least they provide a direction for your plan. They allow you to explain why you are planning *this* study and collecting *these* data. They allow you to "carefully plan in advance."

Making Your Predictions Explicit Allows You to Put Your Rationales in Harm's Way

Rationales are developed to justify the predictions. Rationales represent your best reasoning about the research problem you are studying. How can you tell whether your reasoning is sound? You can try it out with colleagues. However, the best way to test it is to put it in "harm's way" (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003 p. 10). And the best approach to putting your reasoning in harm's way is to test the predictions it generates. Regardless if you are conducting a qualitative or quantitative study, rationales can be improved only if they generate testable predictions. This is possible only if predictions are explicit and precise. As we described earlier, rationales are evaluated for their soundness and refined in light of the specific differences between predictions and empirical observations.

Making Your Predictions Explicit Forces You to Organize and Extend Your (and the Field's) Thinking

By writing out your predictions (even hunches or fuzzy guesses) and by reflecting on why you have these predictions and making these reasons explicit for yourself, you are advancing your thinking about the questions you really want to answer. This means you are making progress toward formulating your research questions and your final hypotheses. Making more progress in your own thinking before you conduct your study increases the chances your study will be of higher quality and will be exactly the study you intended. Making predictions, developing rationales, and imagining tests are tools you can use to push your thinking forward before you even collect data.

Suppose you wonder how preservice teachers in your university's teacher preparation program will solve particular kinds of math problems. You are interested in this question because you have noticed several PSTs solve them in unexpected ways. As you ask the question you want to answer, you make predictions about what you expect to see. When you reflect on why you made these predictions, you realize that some PSTs might use particular solution strategies because they were taught to use some of them in an earlier course, and they might believe you expect them to solve the problems in these ways. By being explicit about why you are making particular predictions, you realize that you might be answering a different question than you intend ("How much do PSTs remember from previous courses?" or even "To what extent do PSTs believe different instructors have similar expectations?"). Now you can either change your question or change the design of your study (i.e., the sample of students you will use) or both. You are advancing your thinking by being explicit about your predictions and why you are making them.

The Costs of Not Making Predictions

Avoiding making predictions, for whatever reason, comes with significant costs. It prevents you from learning very much about your research topic. It would require *not* reading related research, *not* talking with your colleagues, and *not* conducting pilot studies because, if you do, you are likely to find a prediction creeping into your thinking. Not doing these things would forego the benefits of advancing your thinking before you collect data. It would amount to conducting the study with as little forethought as possible.

Part VI. How Do You Formulate *Important* Hypotheses?

We provided a partial answer in Chap. 1 to the question of a hypothesis' importance when we encouraged considering the ultimate goal to which a study's findings might contribute. You might want to reread Part III of Chap. 1 where we offered our opinions about the purposes of doing research. We also recommend reading the March 2019 editorial in the *Journal for Research in Mathematics Education* (Cai et al., 2019b) in which we address what constitutes important educational research.

As we argued in Chap. 1 and in the March 2019 editorial, a worthy ultimate goal for educational research is to improve the learning opportunities for *all* students.

However, arguments can be made for other ultimate goals as well. To gauge the importance of your hypotheses, think about how clearly you can connect them to a goal the educational community considers important. In addition, given the descriptors of scientific inquiry proposed in Chap. 1, think about how testing your hypotheses will help you (and the community) *understand* what you are studying. Will you have a better explanation for the phenomenon after your study than before?

HELPFUL TIP

One potentially useful way to start finding an important area of mathematics education in which to conduct research is to consult with teachers about a problem of practice that affects their students' learning opportunities. If you can connect that problem to research that helps you develop a prediction, you may have a promising candidate for a good research problem.

Although we address the question of importance again, and in more detail, in Chap. 5, it is useful to know here that you can determine the significance or importance of your hypotheses when you formulate them. The importance need not depend on the data you collect or the results you report. The importance can come from the fact that, based on the results of your study, you will be able to offer revised hypotheses that help the field better understand an important issue. In large part, it is these revised hypotheses rather than the data that determine a study's importance.

A critical caveat to this discussion is that few hypotheses are self-evidently important. They are important only if you make the case for their importance. Even if you follow closely the guidelines we suggest for formulating an important hypothesis, you must develop an argument that convinces others. This argument will be presented in the research paper you write.

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Consider Martha's hypothesis presented earlier. When we left Martha, she predicted that "Participating teachers will show changes in their teaching with a greater emphasis on conceptual understanding with larger changes on linear function topics directly addressed in the LOs than on other topics." For researchers and educators not intimately familiar with this area of research, it is not apparent why someone should spend a year or more conducting a dissertation to test this prediction. Her rationale, summarized earlier, begins to describe why this could be an important hypothesis. But it is by writing a clear argument that explains her rationale to readers that she will convince them of its importance.

How Martha fills in her rationale so she can create a clear written argument for its importance is taken up in Chap. 3. As we indicated, Martha's work in this regard led her to make some interesting decisions, in part due to her own assessment of what was important.

Part VII. Beginning to Write the Research Paper for Your Study

It is common to think that researchers conduct a study and then, after the data are collected and analyzed, begin writing the paper about the study. We recommend an alternative, especially for beginning researchers. We believe it is better to write drafts of the paper at the same time you are planning and conducting your study. The paper will gradually evolve as you work through successive phases of the scientific inquiry process. Consequently, we will call this paper your *evolving research paper*.

We believe it is better to write drafts of the paper at the same time you are planning and conducting your study.

You will use your evolving research paper to communicate your study, but you can also use writing as a tool for thinking and organizing your thinking while planning and conducting the study. Used as a tool for thinking, you can write drafts of your ideas to check on the clarity of your thinking, and then you can step back and reflect on how to clarify it further. Be sure to avoid jargon and general terms that are not well defined. Ask yourself whether someone not in your field, maybe a sibling, a parent, or a friend, would be able to understand what you mean. You are likely to write multiple drafts with lots of scribbling, crossing out, and revising.

Used as a tool for communicating, writing the best version of what you know before moving to the next phase will help you record your decisions and the reasons for them before you forget important details. This best-version-for-now paper also provides the basis for your thinking about the next phase of your scientific inquiry.

At this point in the process, you will be writing your (research) questions, the answers you predict, and the rationales for your predictions. The predictions you make should be direct answers to your research questions and should flow logically from (or be directly supported by) the rationales you present. In addition, you will have a written statement of the study's purpose or, said another way, an argument for the importance of the hypotheses you will be testing. It is in the early sections of your paper that you will convince your audience about the importance of your hypotheses.

In our experience, presenting research questions is a more common form of stating the goal of a research study than presenting well-formulated hypotheses. Authors sometimes present a hypothesis, often as a simple prediction of what they might find. The hypothesis is then forgotten and not used to guide the analysis or interpretations of the findings. In other words, authors seldom use hypotheses to do the kind of work we describe. This means that many research articles you read will not treat hypotheses as we suggest. We believe these are missed opportunities to present research in a more compelling and informative way. We intend to provide enough guidance in the remaining chapters for you to feel comfortable organizing your evolving research paper around formulating, testing, and revising hypotheses.

While we were editing one of the leading research journals in mathematics education (*JRME*), we conducted a study of reviewers' critiques of papers submitted to the journal. Two of the five most common concerns were: (1) the research questions were unclear, and (2) the answers to the questions did not make a substantial contribution to the field. These are likely to be major concerns for the reviewers of all research journals. We hope the knowledge and skills you have acquired working through this chapter will allow you to write the opening to your evolving research paper in a way that addresses these concerns. Much of the chapter should help make your research questions clear, and the prior section on formulating "important hypotheses" will help you convey the contribution of your study.

Exercise 2.3
Look back at your answers to the sets of questions before part II of this chapter.

(a) Think about how you would argue for the importance of your current interest.
(b) Write your interest in the form of (1) a research problem, (2) a research question, and (3) a prediction with the beginnings of a rationale. You will update these as you read the remaining chapters.

Part VIII. The Heart of Scientific Inquiry

In this chapter, we have described the process of formulating hypotheses. This process is at the heart of scientific inquiry. It is where doing research begins. Conducting research always involves formulating, testing, and revising hypotheses. This is true regardless of your research questions and whether you are using qualitative, quantitative, or mixed methods. Without engaging in this process in a deliberate, intense, relentless way, your study will reveal less than it could. By engaging in this process, you are maximizing what you, and others, can learn from conducting your study.

In the next chapter, we build on the ideas we have developed in the first two chapters to describe the purpose and nature of *theoretical frameworks*. The term theoretical framework, along with closely related terms like conceptual framework, can be somewhat mysterious for beginning researchers and can seem like a requirement for writing a paper rather than an aid for conducting research. We will show how theoretical frameworks grow from formulating hypotheses—from developing rationales for the predicted answers to your research questions. We will propose some practical suggestions for building theoretical frameworks and show how useful they can be. In addition, we will continue Martha's story from the point at which we paused earlier—developing her theoretical framework.