HOW WE THINK

A THEORY OF GOAL-ORIENTED DECISION MAKING AND ITS EDUCATIONAL APPLICATIONS

PREFACE AND CHAPTER 1

Alan H. Schoenfeld
Elizabeth and Edward Conner Professor of Education
Graduate School of Education
EMST, Tolman Hall # 1670
University of California
Berkeley, CA 94720-1670
alans@berkeley.edu

PREFACE

This book is about the choices people make as they are involved in familiar, "well practiced" activities. For different individuals, such activities might include one or more of the following: shopping for a meal or preparing one, answering the phone in a business office, fixing a car, writing an essay, solving a mathematics problem, teaching a lesson, or performing some medical or dental procedure. Here are the core questions I address.

> Suppose a person is engaged in some well practiced activity. What determines what that person does, on a moment-by-moment basis, as he or she engages in that activity? What resources does the person draw upon, and why? What shapes the choices the person makes? What accounts for the effectiveness or lack of effectiveness of that person's efforts?

The main claim in the book is that what people do is a function of their *resources* (their knowledge, in the context of available material and other resources), *goals* (the conscious or unconscious aims they are trying to achieve) and *orientations* (their beliefs, values, biases, dispositions, etc.). I argue that if enough is known, in detail, about a person's orientations, goals, and resources, that person's actions can be explained at both macro and micro levels. That is, they can be explained not only in broad terms, but also on a moment-by-moment basis.

That people are consistent on the macro level is easy to see: everyone has routines for familiar activities. For example, the automobile mechanic and the doctor both have diagnostic routines and standard follow-ups when the diagnoses reveal particular patterns. The cook has certain prep routines and standard methods of preparation. The teacher has a range of routines for collecting homework, presenting new material, checking on student understanding, and so on. In fact, routines structure the vast majority of what people do when they are in familiar territory – and routines structure people's activities down to the micro level. For example, the chunk of a lesson devoted to reviewing homework comes as part of the teacher's overall lesson structure. It decomposes into smaller chunks (depending on the teacher's style it might be holding a Q-and-A session, having students present work at the board, or something else), each of which decomposes into smaller chunks, down to the level of sentence-by-sentence interactions with students. If things stay within the realm of the familiar, choices are easy and effortless.

Of course, things don't always go as one expects. The question is, what does the individual do then? Looked at from the analyst's point of view, is it possible to explain the choice the person makes? Some choices just don't seem rational, and such choices can often be consequential. Can they be explained in a consistent and rigorous way, rather than by invoking "random behavior" or by producing a series of ad hoc explanations? In this book I argue that if one understands enough about the person's resources, goals, and orientations, then one can often understand, explain, and even model actions and decisions that seem unusual or anomalous. Here are three examples.

- A beginning teacher is working through some elementary algebra problems with his students. He knows the point he wants to make, and he knows more than enough mathematics to explain it. His students are reasonably well behaved, responding to the questions he poses. Yet, at a crucial point in the lesson, he slumps at the board, seemingly unable to provide the students with the simple explanation that we know he knows. Why did this happen?

- An experienced teacher is working through a familiar lesson when a student makes a complicated and somewhat ambiguous comment. Various teachers might respond in any of a number of ways, from “Interesting comment. I’ll talk to you about it after class” to “Let’s sort that out.” Can we say what this particular teacher would do, and why?
- A teacher-researcher has been working hard to get her third grade class to focus on a particular issue. She interrupts what she has been doing to pursue something else, disrupting the continuity of the lesson. Is there a way to understand what she is doing in a way that explains this seemingly random act?

In all three cases, each of which is described in Part 2 of this book, I argue that the acts in question can be seen as quite reasonable, once one knows enough about the individual’s orientations, resources, and goals. Further, I argue that understanding these teachers’ goals, resources, and orientations allows one to construct coherent explanations of everything they did during the extended lesson segments that included those actions. Unproblematic actions are explained by individuals’ access to routines (or – choose your term from the psychological and Artificial Intelligence (AI) literatures – access to scripts, schemata, frames, etc.), which are part of the resource base. How and why these particular resources are selected will be seen to be a function of the individual’s orientations. Thus, the theory laid out in this book provides explanations of both the routine and non-routine behaviors of three very different teachers, on a moment-by-moment basis.

I submit that if one can understand and explain teachers’ in-the-moment decision making, then one can understand and explain any well practiced activity, for example those referred to in the opening paragraph of this preface. The core of this book consists of detailed analyses, on a line by line basis, of three classroom lessons. The "surround" consists of a discussion of the general theory exemplified by the teaching analyses, including a plausibility case for the argument and some non-classroom examples. Here is a road map for what follows.

Part 1 provides the general argument that all well practiced behavior can be explained, on the macro and micro levels, as a function of an individual's orientations, goals, and resources. Chapter 1, "From problem solving to teaching and beyond," provides some background and context. My early research was on mathematical problem solving. The work described in this book is a natural outgrowth of that research, and it answers some major questions that I was unable to answer when my 1985 book, *Mathematical Problem Solving,* was published; Chapter 1 explains how I got from there to here. Chapter 2, "The big picture," tries to provide what its title suggests. I explain at a general level how the theory works, and I provide details regarding the major constructs it uses: goals, orientations, resources, and the decision making mechanisms that explain how and why people make the choices they do. Chapter 3, "Reflections, caveats, doubts, and rationalizations," reflects on the enterprise. It addresses questions such as the following. Is it plausible to claim to explain people's inner thoughts? What does it mean when I attribute goals, resources or orientations to people, or when I claim to model their actions on the basis of these? My goal is to explain why I do things the way I do, and to discuss the strengths and limitations of this kind of approach.

Part 2 offers detailed models of three teaching episodes. I introduce a representation that is useful for "parsing" (representing and analyzing) episodes of teaching. Then, using the theoretical framework described in Part 1, I provide line by line analyses of the three lessons from which I chose the examples of teacher decision making given above. Chapter 4, “Lesson Analysis 1: A beginning teacher carrying out a traditional lesson,” describes a lesson segment taught by Mark Nelson, a student teacher in Berkeley’s teacher preparation program. Much of the analysis is straightforward, but then there is the issue raised in the first example above. Nelson is stymied mid-lesson, seemingly incapable of providing his students with a simple mathematical explanation. The analysis will explain why. Chapter 5, “Lesson analysis 2: An experienced teacher carrying out a non-traditional lesson,” analyzes an hour-long lesson taught by Jim Minstrell, an award-winning teacher-researcher. The analysis includes a discussion of why, when one understands Minstrell’s resources, orientations, and goals, there is little question as to how he will respond to the complicated and somewhat ambiguous comment made by the student. It also introduces a classroom routine that is used extensively by Minstrell – a routine that has the potential to be a powerful tool for teachers’ professional development. Chapter 6, “Lesson analysis 3: Third graders! A non-traditional lesson with an emergent agenda,” analyzes a much studied lesson segment taught by Deborah Ball, who is also a highly regarded teacher-researcher. Two things emerge from that analysis. The first is that, although her teaching looks radically different from Minstrell’s in some ways, Ball uses what is structurally the same routine as Minstrell for soliciting comments from students. The second is that the seemingly odd move that Ball makes, disrupting her own announced agenda, can be seen as quite reasonable once one understands her orientations, goals, and resources.

Part 3 returns to the big picture. Chapter 7, "The analysis of a doctor-patient consultation – An act of joint problem solving" presents the analysis of a consultation I had with my doctor. This is an attempt to begin to make good on the claim that the framework illustrated in Part 2 applies as well to issues of medical practice (and by extension, to other well practiced activities). The doctor clearly employs a standard routine, which shapes most of her interactions with me; her decision making is easy to understand and is consistent with the theory. In addition, since there were only two of us in the conversation, I analyzed the actions of both participants. It had been a productive conversation – and it turns out that the analytic framework helps to explain why. This, in turn, suggests new ways of looking at classroom interactions. Chapter 8, "Next steps," looks at applications and generalizations. In Chapter 8 I describe a hypothetical developmental trajectory for teachers, and I discuss issues of professional development for teachers in the light of the work discussed in this book. Given that resources, orientations, and goals shape teacher behavior, and that they tend to change slowly, there are implications for those of us concerned with helping teachers to grow as professionals. And, of course, there are questions of what to explore next, given what the book has laid out.

Readers with different interests will want to focus on different parts of the book. Those with a general interest in the big picture (how and why people do what they do) may want to focus on chapters 1 and 2 (especially 2), the introduction to part 2 and one of the teaching chapters (to get the flavor of the analysis), and chapters 7 and 8. Those with a stake in teachers' professional development may want to take a closer look at Part 2 and chapter 8. Those who are interested in the details of models of people's behavior and their strengths and limitations will, I hope, give the entire book a thorough going-over.

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Note

This book draws upon a wide range of articles that I have written since becoming an educational researcher. In particular the analytic chapters 4, 5, and 6 revisit and modify papers such as Schoenfeld (1998b, 2002, 2008) and Schoenfeld, Minstrell, & van Zee (2000).

CHAPTER 1:

FROM PROBLEM SOLVING TO TEACHING AND BEYOND

Chapter 1

FROM PROBLEM SOLVING TO TEACHING AND BEYOND

Introduction

This book focuses on how and why people make the choices they make as they engage in a wide range of knowledge intensive activities. A main emphasis is on studies of teaching, my goal being to offer a theoretical account of the (not necessarily conscious) decisions that teachers make amidst the extraordinary complexity of classroom interactions. A full theoretical account of teaching would not only characterize the "big" decisions such as the structure of a lesson, but the small ones (e.g., how the teacher will answer a particular question) as well. I believe that if you can fully explain decision making during teaching, then you can explain decision making in just about any knowledge intensive domain.

The goal of this chapter is to provide the context for the current book. My early research was on mathematical problem solving. My major goals were to understand problem solving, and then to use that understanding to help people get better at it. In fundamental ways I view teaching as a (much more complex) problem solving activity, and my goals for this book parallel the goals for my problem solving work. The better we can understand a range of complex knowledge intensive activities, including teaching, the better we can help people become effective at them. Here I explain how the current work is an outgrowth of the earlier work on problem solving.

The central theoretical contribution of my problem solving research (see, e.g., Schoenfeld, 1985) was what I called a framework for the analysis of mathematical problem solving behavior. In simplest terms, I claimed the following:

If you want to know why people's attempts to solve challenging (mathematical) problems are successful or not, you need to examine their:

- *knowledge base* – just what (mathematics) do they know?
- *problem solving strategies,* a.k.a. heuristics – what tools or techniques do they have in order to make progress on problems they don't know how to solve?
- *monitoring and self-regulation* – aspects of metacognition concerned with how well individuals "manage" the problem solving resources, including time, at their disposal, and
- *beliefs* – individuals' sense of mathematics, of themselves, of the context and more, all of which shape what they perceive and what they choose to do.

My argument was that those categories are necessary and sufficient for understanding problem solving success or failure. The categories are necessary in the sense that if any of them are left out of an analysis of someone's problem solving attempt, the analyst runs the risk of missing the key factor that explains why the individual did or did not succeed. That is, there are situations where mathematical knowledge is the make-or-break factor in a problem solution. There are situations where the use of heuristic strategies brings an otherwise inaccessible solution within reach. There are situations where the effective use of available resources puts a problem solver in a position to obtain a solution, and situations where the inefficient or ineffective use of time or knowledge results in failure to solve a problem that the individual "should have" been able to solve. And, there are situations where people's beliefs (e.g., about their capacity, about what is considered a "legitimate" approach in a particular context, or about the amount of time and energy that should be spent on a problem before declaring it impossible) either propel them toward success or guarantee failure. In sum, each of the categories listed above is necessary for analysis. I argued as well that the four categories are sufficient, in that every root cause of success or failure will be found within them.

The framework, the data, and the arguments have stood the test of time[1]. Over the past quarter century a substantial amount of research in mathematics education and in education more generally has emerged to confirm them. So, what else is there to say?

There are two main things to say. The first is that *Mathematical Problem Solving* offered a framework for looking at problem solving, but not a theory of problem solving. A framework tells you what to look at and what its impact might be. A theory tells you how things fit together. It says how and why things work the way they do, and it allows for explanations and even predictions of behavior. In my earlier work I could account for success or failure by describing the impact of the knowledge and decisions made by the problem-solver. What I couldn't account for was how and why the problem solvers drew on particular knowledge or strategies, or how and why they made the decisions they did. That's the focus of this book.

The second main point has to do with the scope of the phenomena that the theory covers. My earlier work dealt with mathematical problem solving. Most of the analytic work was conducted in my laboratory, a quiet place where I gave people challenging mathematics problems to work on.[2] But that's too narrow, along a number of dimensions.

[1] I later (Schoenfeld, 1992) added the category of *practices* as something essential to examine. The idea is that the practices in which one engages (e.g., "school mathematics") play a causal role in shaping one's beliefs and resources. The first four categories of the framework suffice for examining problem solving "in the moment."

[2] The ideas were then tested in my problem solving courses. That's how I got "real world" robustness, and transcended the contextual limitations of laboratory studies. Classroom experiences also suggested ideas for more focused laboratory study, so that theory, lab studies, and practice all interacted productively.

The first dimension is content. I studied mathematical problem solving because I was conversant with mathematics. But, what would one expect a framework or a theory of problem solving in physics to look like? From my perspective a framework for examining success or failure in physics problem solving would have to examine the following:

(a) the knowledge base (in this case the understanding of relevant physics content),
(b) access to problem solving strategies, some of which are tied to physics content and some of which are more general;
(c) monitoring and self-regulation; and
(d) relevant beliefs.

Surely that seems plausible: physics and math are pretty close. It's likely that the same would be the case for other quantitative domains. But what about a different kind problem solving domain – say writing?

Writing is clearly a problem solving activity, in that one can conceptualize any writing task as a problem solving exercise: the problem (or, the goal) is to produce a body of text that achieves a certain purpose. That purpose might be to demonstrate one's knowledge of Russian literature, to obtain a job interview, or to explain a theory one has been working on for thirty years. For all of these purposes, the following holds.

(a) What the writer knows, at the level of having something to say and at the level of being able to produce suitable and grammatical text, is critically important.
(b) Writers use scads of heuristic strategies, which range from small-scale ("use topic sentences") to large-scale ("make an outline before producing text") to more

broadly suggestive ("to make sure people get your point, tell them what you're going tell them; tell them; then tell them what you told them").

(c) Almost everyone has had the experience of writing for a while and suddenly realizing that the direction of the text has changed or the intended audience has been lost, and that a lot of text will have to go in the trash can or be recycled. This "loss of audience" is a failure of monitoring and self-regulation, and evidence of its importance.

(d) As anyone who has read student essays can tell you, students who believe that writing is just putting down on paper what's in your head will produce very different text from those students who believe that writing is hard work, requiring multiple refinements in order to convey one's ideas![3]

In sum, there is good reason to believe that the factors that shape successful or unsuccessful efforts at writing are the same as the factors that shape successful or unsuccessful efforts at problem solving in mathematics or physics. Arguably, the same is the case in all problem solving domains. Take cooking, for example. Producing a meal can be seen as trying to achieve something, and thus as a problem. Like all other problem solving, it is goal-oriented. Knowledge, strategies, and techniques (not to mention material resources) are just as important in cooking a fine dinner as they are in solving a mathematics problem. With a bit of reflection, one sees the critical importance of monitoring and self-regulation (timing and coordination are critical) and beliefs ("fungi are fungi and liver is liver" thought a friend, substituting brown mushrooms and chicken

[3] The contents of this paragraph are well known within the research community that studies writing (see, e.g., Bereiter & Scardamalia, 1987; Hayes, 1996; Hayes & Flower, 1980, 1986). The main point here is that writing and many other domains can productively be thought of as goal-oriented or problem solving activities, and analyzed accordingly.

livers respectively for truffles and foie gras in what was intended to be a rather elegant dish!). In sum, there is a plausibility case, buttressed by a quarter century of literature in a wide range of fields, that the framework for examining the success or failure of attempts at mathematical problem solving presented in *Mathematical Problem Solving* is really a framework for looking at the factors that shape success or failure in any problem solving activity.

A second dimension is that of social interactions. Early problem solving research in most fields was done in the laboratory, away from other people. However, the vast majority of decision making and problem solving involves or is influenced by others. A widely applicable theory of decision making should explain how people make decisions in often highly interactive social contexts.

A third dimension involves the dynamic character of the environments in which people make decisions. Mathematics problems rarely change their character while you're working on them. But the real world offers loads of surprises, and a broad theory of how people act should explain their behavior amidst dynamically changing circumstances. My aim in general has been to explain the choices people make in a wide range of knowledge intensive, highly interactive, dynamically changing environments. Teaching scores high on all of these dimensions, and it is obviously important. Thus my goal was to explain teaching – but that was too large a goal to bite off at once.

Toward greater generality

A logical step in my research program was to study situations that were socially dynamic, but not reflecting the full-blown complexity of the mathematics classroom. Thus I moved to studies of one-on-one mathematics tutoring. In a tutoring session the problem solver (the tutor) is working with what appears to be a straightforward goal: trying to help someone else learn some specific mathematics. Yet the situation as understood by the tutor – the perceived problem state – can and often does change dramatically in the midst of problem solving. Here are two typical examples of how.

Example 1. Imagine a student and tutor working together on a calculus problem. All seems to be going well. The student gets to a point where some algebraic manipulation is called for, and writes

$$(a+b)^2 = a^2 + b^2.$$

Ouch! The tutor had assumed that the student's algebraic foundation was solid, and now sees that it is not. This calls for a major decision: is it preferable to make a simple correction ("Watch it, the square should be $a^2 + 2ab + b^2$") and continue with the calculus problem, or is the algebraic error important enough to warrant serious attention? Either way, the tutor's perception of the problem state has changed dramatically in just a few seconds and something needs to be done about that.

Example 2. Perhaps later in the same session, the student says something that is ambiguous or that sounds slightly odd, suggesting a shaky understanding of an underlying idea. The tutor asks for a clarification and the student slumps visibly in response. The tutor has just crossed some line, although it may not be clear what that line is. Again, the tutor faces a major decision. Should he or she persevere at the risk of student disaffection, or back off and return to the issue when the student seems less vulnerable? If the tutor decides it is preferable to back off, what's the next direction to pursue at this point?

Although the catalytic events differ in these two examples – the first was related to the student's content understanding and the second to an affective issue – something similar has happened in theoretical terms. The tutor had certain high priority goals and was working toward achieving them, implementing resources that had been selected to that end. Something happened that called for a re-evaluation of the problem state. With that re-evaluation, a series of decisions was called for. Should the tutoring session continue along the same path or should the tutor modify or abandon the current goals? If the same goals are maintained, should the tutor persevere in the same approach or try an alternative approach? If the tutor modifies the top-level goals, how does he or she choose what to do next?

I claim that in general such decisions are based on the tutor's resources[4], goals and orientations[5], as they play out in the particular context. Does the tutor think the student's algebraic error is a slip or an indication of a serious misunderstanding? How much time is left in the tutoring session? Is there a test coming up? Is there time to remediate the algebra misconception if it turns out to be a deep-rooted misconception? What tools does the tutor have available to address it? Does the tutor feel a need to deal with issues as they arise, or does he or she feel comfortable letting certain things go? All of these factors shape the tutor's decisions regarding what to pursue and how to pursue it. The same holds with regard to the tutor's potential response to an affective issue. Is the tutor focused on content, affect be damned? If so, he or she will persevere in getting a clarification, although perhaps with a bit of cajolery. Does the tutor sense that the student

[4] The tutor's resources may include techniques for dealing with content- and affect-related issues, as well as texts, "hands on" materials, and so on.
[5] Synonyms for "orientations" that seem especially appropriate in various contexts are beliefs, dispositions, preferences, values, and stances. See Chapters 2 and 3 for fuller discussions of these and other terms.

is on the edge, and that persevering would be risky? If so the tutor may back off, even if some of the student's understandings are left unexamined for the time being. Whatever happens, the tutor will have established a modified set of goals and drawn upon his or her resource base for means of achieving them. In short, the tutor's orientations, including his or her beliefs (about mathematics, about the student, about the interaction) and values (what's most important about the mathematics, about the student, about the interaction?) are a major factor in the re-prioritization of goals (establishing what the tutor will now set out to achieve) and in the selection and application of resources to achieve those goals.

This simple story line – that one's decisions about what goals to pursue, and how to pursue them, are made on the basis of our current resources, goals and orientations – is the core idea in this book. Over the course of the book I will explain what I mean by the key terms *resources*, *goals* and *orientations*, and how decisions are made; I will make a case that a very large proportion of our actions are indeed of this type.

When I began my research on tutoring there existed two non-intersecting bodies of literature on tutoring. One, in the cognitive-analytic tradition, was largely devoted to the construction of computer-based tutors for subjects such as arithmetic, algebra and geometry. These models of content understanding were based on detailed studies of effective problem solvers' content knowledge. These computer-based tutorial systems had fine-grained models of the desired goal states (the knowledge states for students). In general, however, their pedagogical theories and their human interfaces were on the primitive side. A complementary "human factors" literature focused on the interactive aspects of tutoring related to affect, motivation, and communication: what did the tutor do to support, encourage, motivate or empower the student mathematically? In this literature, details related to the specific content were given little attention. An issue with regard to motivation, for example, was whether all praise was equally motivating, or whether praise was more effective when the student had achieved something non-trivial. As a member of my research group put it, the ITS (intelligent tutoring system) literature was all about content, with a bit of human factors thrown in; the human factors literature was all about interaction, with content considerations serving as the context for the interactions.

As indicated by the examples above, this couldn't be right – tutors must be attentive to content and affect at the same time. In a tutoring session, what matters is that the student has done something that demands immediate attention; whether the student has made an algebra mistake or displayed signs of disaffection is immaterial. Any theory of tutoring has to be equally sensitive to content-related and interpersonal matters.

The approach we developed, which focused on the tutor's goals as the driving force behind the tutor's choices of action, did just that. The way we characterized things, it didn't matter why the tutor thought something was important; it just mattered that he or she did. If achieving something was important enough to the tutor, doing so became a top-level goal, and the tutor pursued it. When that goal was satisfied or displaced, new paths were chosen to meet the new goals. Goal prioritization was based on what the tutor felt or believed to be most important for the student or for the interaction, and once goals were prioritized the tutor acted by implementing resources selected in the service of those goals. This simple approach allowed us to characterize, in fine-grained detail, the actions taken by mathematics tutors in a range of tutoring sessions (see, e.g., Schoenfeld, Gamoran, Kessel, Leonard, Orbach, & Arcavi, 1992).

As complex as it is, tutoring pales in complexity when compared to classroom teaching. In the tutoring sessions we studied, the tutor entered with a specific agenda (to work through a particular set of problems) and had to focus on just one person, the person being tutored. There were occasional untoward events of the types given in examples 1 and 2 above; but by and large the tutors' decision making was straightforward to characterize in goal-oriented terms. In contrast, although teachers also typically enter their classrooms with specific agendas in mind, classroom reality confronts teachers with myriad contingencies and myriad things to attend to. There is the content, of course, complicated by the fact that every student has a different understanding of it. There is a wide range of interpersonal issues to be sorted out. There are unexpected fire drills and countless other interruptions to a lesson. The question we posed was, could the kind of goal-oriented theoretical approach we had developed for characterizing and modeling tutoring apply to something as complex as teaching?

In a word, yes. Asking the questions "What is the teacher trying to achieve at the moment, and how did that goal (or those goals) become the teacher's highest priority for the moment?" turns out to be central in understanding teachers' classroom actions. Moreover, the two major kinds of priority-setting events for teachers turn out to be the natural analogs of the two major kinds of priority-setting events for tutors.

Most of a tutoring session is shaped by the tutor's agenda: there is a planned set of activities[6] and, barring unforeseen events, the tutor will work through them. Goals cascade naturally: a top level goal may be to make sense of a concept by working through various problems, so the first major subgoal is to work through the first problem, which

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[6] The plan or agenda could have been made in advance, or it could be emergent: the student might ask for help with a particular topic, and the tutor turns to the exercises in the book dealing with that topic. Either way, there is a guiding, goal-oriented structure to shape the activity sequence.

may entail various sub-subgoals; and so on. But unforeseen events of the types mentioned above may call for re-prioritizing. If the student reveals a serious misconception or gets restless, then the tutor may have to change course (establish new goals), at least temporarily.

Much the same is the case with teaching. The vast majority of a teacher's actions in the classroom are shaped by the teacher's agenda, which may be encapsulated in a lesson plan and fleshed out in the teacher's lesson image (the teacher's envisioning of how things are likely to play out). Barring unforeseen events, that agenda provides a macro-level goal structure for the lesson (e.g., take roll, make announcements, answer questions, work through homework, introduce new topic, have the class work in groups, bring things to a close, assign homework), with each activity having its own micro-level goal structure as well. In teaching just as in tutoring, unforeseen events can be consequential and may call for re-prioritizing. The re-prioritization determines the direction of the interaction. This simple claim, which we came to understand over the course of our teaching studies, lies at the heart of this book: *If you can understand (a) the teacher's agenda and the routine ways in which the teacher tries to meet the goals that are implicit or explicit in that agenda, and (b) the factors that shape the teacher's prioritizing and goal setting when potentially consequential unforeseen events arise, then you can explain how and why teachers make the moment-by-moment choices they make as they teach.*

Of course there is more. It goes without saying that the teacher's knowledge (more broadly, the set of intellectual, material, and contextual resources available to the teacher) is fundamental in shaping the teacher's decision making. What a teacher can or cannot do in the classroom is clearly a function of what he or she knows, what material and other resources are available, and what constraints are in place (e.g., state or district testing mandates, available texts, and so on). This was made very clear, in different ways, in our first two studies of teaching. In Chapter 4 we will see that part of the cause of Nelson's difficulty was that he lacked certain pedagogical content knowledge; a more experienced teacher might have anticipated the difficulty Nelson encountered and employed various methods to avoid it. By contrast, during the lesson discussed in Chapter 5 Jim Minstrell was able to think on his feet in part because much of what his students said was familiar. Resources play a major role, as one would expect.

What we saw over time was just what a critical role the tutor or teacher's orientations played as well. One can imagine the case in the tutoring examples given above. Suppose student and tutor are working happily along when the student makes the error mentioned in example 1 above, writing "$(a+b)^2 = a^2 + b^2$." What will the tutor do? That depends on what matters to the tutor. If the tutor is procedurally oriented and wants to insure that the student doesn't make this mistake again, the tutor may point out the error, state clearly that $(a+b)^2 = a^2 + 2ab + b^2$, and give the student a few practice problems to make sure that the student has the skill down pat. If the tutor is more conceptually oriented, he or she may work through the distributive law, discuss area models of multiplication, or work through some other preferred method of explaining *why* $(a+b)^2 = a^2 + 2ab + b^2$. The tutor's choice thus depends on the tutor's orientations (what does he or she think really counts?) and on the resources at his or her disposal (comfortably familiar explanations are likely to be chosen). If you know enough about the orientations of the tutor, you can explain, and possibly even predict, the choices the tutor will make at consequential points in the tutoring session.

The impact of orientations became powerfully clear when we came to understand Nelson's lesson. Details will be given in Chapter 4, but the top-level explanation is this: telling students the answer to the question he had posed without first eliciting the key elements of the solution from them was a violation of his conception of how he should teach. Having deprived himself of the "telling" option, he was painted into a corner with no way out.

We came to take a more fine-grained look at orientations and their impact on consequential decision making in our study of the lesson discussed in Chapter 5. I introduce the discussion here, to illustrate the mechanism by which orientations work. The lesson was taught by Jim Minstrell, a well known and highly regarded physics teacher-researcher.

From Minstrell's perspective, physics is a sense-making activity: physics is not primarily about implementing formulas but about codifying and making sense of patterns in the world. Minstrell wants his students to see physics that way. He wants them to feel that his physics classroom is a place where they can sort through situations and make sense of them. He has designed his first lessons with care, to emphasize the point that human discretion is involved even in something as ostensibly straightforward as the act of measurement. His classroom actions are intended to reinforce his sense-making message. For example, Minstrell often waits ten seconds or more after posing a question before he says anything. And rather than answering a question himself, he will most frequently respond by turning the question – possibly reformulated or clarified – back to the class for discussion. Minstrell calls such moves *reflective tosses*. They are a central component of his teaching style.

In the lesson prior to the one discussed here, Minstrell and his students had discussed discretion in data gathering and analysis. Do you trust some data more than others? (For example, does it matter who takes a blood sample for analysis?) Do you necessarily use all the data that were gathered? (In some athletic competitions, the highest and lowest scores assigned by judges are dropped automatically. Why?) How do you combine the numbers that you have decided to use, once you have made decisions about whether to use outliers or suspect data?

To anchor the discussion in a concrete example, Minstrell had asked eight students to measure the width of a table in his classroom. The students arrived at these values:

106.8; 107.0; 107.0; 107.5; 107.0; 107.0; 106.5; 106.0.

The question that framed the class's discussion was this: "What is the best number for the width of the table?" Minstrell (denoted below by M) fielded suggestions from students, working through them one at a time. For example, when a student suggested "average them," he responded with a reflective toss and then an elaboration:

S: Average them.

M: OK. [writes "average them" on board] We might average them. Now what do you mean by "average" here, S?

S: Add up all the numbers and then divide by whatever amount of numbers you added up.

M: All right. That is a definition for "average." In fact, that's what we'll call an "operational definition." . . . [Minstrell elaborates on the definition] . . .
OK?
Any other suggestions for what we might do? So we can average them –

[8s pause]

Any other suggestions there for what we might do to get a best value?

The discussion continued similarly with the consideration of mode. There too – indeed, for the vast majority of this lesson – Minstrell was on familiar ground, employing well-established routines. The presence of his top-level goal structure and easy access to those routines allowed the lesson to proceed smoothly.

When the discussion of mode concluded Minstrell once again asked, “Anybody think of another way of giving a best value?” A student said,

> This is a little complicated but I mean it might work. If you see that 107 shows up 4 times, you give it a coefficient of 4, and then 107.5 only shows up one time, you give it a coefficient of one, you add all those up and then you divide by the number of coefficients you have.

This was new and Minstrell had to do something in response. There are many ways a teacher might react. What shaped his decision? Consider a spectrum of plausible responses, each of which would be used by a substantial number of teachers:

A: “That’s a very interesting question. I’ll talk to you about it after class.”

B: “Excellent question. I need to get through today’s plans so you can do tonight’s assigned homework, but I’ll discuss it tomorrow.”

C: “That’s neat. What you’ve just described is essentially the ‘weighted average.’ Let me briefly explain how you can write a formula using coefficients similar to the way you’ve described, and that gives the same numerical result as the average.”

D: “Let me write that up as a formula and see what folks think of it.”

E: “Let’s make sure we all understand what you’ve suggested, and then explore it.”

Each of these responses has advantages and disadvantages. For example, response A praises the student (slightly) and allows the teacher to pursue the lesson plan without modification, but it shuts down an opportunity to build on student inquiry. Responses B and C do the student the honor of taking the suggestion seriously and give the teacher a chance to address the content in greater depth. The downsides to these options, depending on one's perspective, are that they take a bit more class time than response A, and at the same time they depend on teacher exposition as opposed to having the students doing the sense making. Response D has the students doing some of the sense making, but it is more costly in terms of class time than the previous options and does not address potentially interesting issues about the denominator. Response E involves a substantial amount of student sense making, but that opportunity comes at a significant cost in terms of time.

Which of these options a teacher will pursue depends on that teacher's orientations (the teacher's beliefs, values, and preferences in this context) and which resources the teacher can bring to bear in support of the option he or she has chosen. The teacher who is concerned about getting through the day's lesson without interruption or who is challenged by the mathematics in the student's statement and wants to stay on safe ground may well choose option A or B. In contrast, Minstrell places a high value on student inquiry and he has the resources to pursue the issues raised in the student's comment. For him, response E is a natural choice.

As explained in Chapter 5, Minstrell's decision making can actually be modeled: a quantification of the subjective valuations that he associates with different outcomes (honoring student inquiry, losing time, etc) makes it clear that responses A, B, and C are very unlikely choices for him, and that option E is preferable by a wide margin to option D. Moreover, this kind of subjective valuation can be used in general to explain the kind of consequential decision making that occurs when teachers (and others) are confronted by unforeseen events.

In a nutshell, the Minstrell story is this. When he is on familiar ground his activities are structured by his agenda, which is heavily influenced by his orientations. There is a natural goal structure to his activities, structured at the top level by his agenda and at more fine-grained levels by the well practiced routines he selects and implements to achieve that agenda. When something unforeseen happens, fresh decision making is called for. Minstrell's decision about what to pursue and how to pursue it is shaped in fundamental ways by his orientations and the resources at his disposal. Thus Minstrell's routine and non-routine decision making can be fully characterized as a function of his resources, goals, and orientations.

As my research group (the Teacher Model Group, or TMG) completed the analysis of Minstrell's lesson, I became increasingly confident that our approach would be adequate to characterize teaching in general. The next step was to find a good test case. Fortunately, at a professional meeting I saw Deborah Ball present a perfect candidate. The lesson she discussed, which has become well known as the "Shea Number" lesson, took place in Ball's third grade class. The students differed substantially from those we had studied; the content was different; the style of the class was different. Moreover, Ball made one particular move early in the lesson that appeared to seriously undermine her announced agenda. Some observers had called that move a "mistake"; it was certainly not apparent why one would make it.

This was ideal. If Ball's decision making during the lesson segment of interest could be explained, then the core theoretical ideas we had developed were truly robust; if we failed to explain them, then the limits to the ideas were clearly established. It took TMG a long time to sort out the details, which are given in Chapter 6. The bottom line is that there was a clear (although subtle) structure to the interactions in the lesson segment. Ball employed a routine that is in essence the same routine that Minstrell used at the beginning of his lesson. In addition, Ball's unusual decision can be seen as quite reasonable once one understands what drove it. In short, what took place in that lesson segment can be characterized in terms of the major constructs of the theory. The fact that all three lessons (Nelson's, Minstrell's and Ball's) can be characterized on a line by line basis as a function of the teachers' resources, goals, and orientations suggests strongly that this approach can be used to characterize all teaching.

The final step of my theoretical line of argument is to see whether the approach taken here might serve to characterize much of human goal-oriented behavior in general. As noted earlier, I think of both problem solving and teaching as goal-oriented behaviors; moreover, a great deal of human behavior – e.g., cooking, writing, or treating a patient – can be viewed as knowledge intensive, goal-directed problem solving. In Chapter 2 I argue (at a heuristic level, without the same level of detail that characterizes the studies of teaching that comprise the core of this book) that the theoretical framework involving resources, goals, orientations and decision making discussed here serves equally well to characterize a wide range of activities, whether they are short term and routine (as in making breakfast) or long-term and anything but routine (as in writing this book).

I do have one more serious test case of the generality of my arguments, given in Chapter 7. Like teaching, health care is a knowledge intensive, well practiced domain. It has been studied extensively in the literature. There are, for example, artificial intelligence models of medical diagnosis and empirical studies of the factors that shape doctors' decision making. On the basis of the literature there was a reasonable chance that the analytic approach TMG had employed to study teaching could be used to study doctor-patient interactions. Partly as a test case but partly for fun I asked my doctor if I could tape one of our conversations and analyze it. She said yes, and Chapter 7 is the result. A goal-oriented analysis of both of our roles in the conversation indicates the mechanisms by which we interacted with each other, and why our conversation turned out to be as productive as it was. It also suggests that the approach used here can be profitably applied to other domains as well.

I hope by now to have explained some of the evolution of my ideas, and to have made a plausibility case for the theoretical orientation in this book. Of course, the introductory descriptions in this chapter represent a promissory note. The devil is in the details, which follow in subsequent chapters.

Notes on connections

This book has myriad antecedents and is connected to multiple literatures. Directly or indirectly, the ideas put forth here draw from many intellectual traditions. These include theories of unified cognition, as exemplified by Newell (1990); analyses of planning, exemplified by pioneering work such as Miller, Galanter, and Pribram (1960) and elaborated in work such as Schank and Abelson (1977); theories of teaching, specifically of mathematics teaching as exemplified by Lampert (2001); theories of decision making, especially work on subjective expected utility, as exemplified by Savage (1954). So what makes this book distinctive? How does it differ from each of the works listed above and the traditions they represent?

This book is similar in ambition to Newell's and draws upon many of the same ideas, but it differs in some fundamental ways. One is grain size. Newell's (1990) focus on the computational implementations of his ideas had, from my perspective, significant affordances and constraints. On the plus side, a running artificial intelligence (AI) program provides a clear existence proof that ideas can work the way the author says they can. On the minus side, the problem with AI is that there may be critically important constructs that don't (yet?) have computational instantiations, e.g., some aspects of metacognition and of orientations. If one is limited either theoretically or empirically by what one can build into a computer program, then one may not be taking into account all of the things one should be. This book does not have Newell's level of existence proof, although I try to adopt some of the same spirit: one can think of the models in chapters 4, 5, and 6 as conceptual *gedanken-experiments* – the first steps toward models that, were one computationally inclined, might be elaborated in further detail. The ideas in this book diverge from Newell's in that I place a different emphasis on underlying phenomena. For example, I assign an absolutely central role to orientations as a fundamental factor shaping human decision making.

Similarly, I draw upon the fundamental notion of plans (often implemented as routines) discussed by Miller, Galanter, and Pribram (1960), and Schank and Abelson (1977). However, my discussion of plan instantiation at multiple levels of grain size, the mechanisms by which plans are invoked or terminated, and the overall coherence of decision making goes beyond the structures they described. The idea of representing subjective valuations computationally is derived from Savage (1954), but it is used both more narrowly and more broadly. My use is narrower in that I invoke subjective expected utility almost exclusively for non-routine (although often consequential) events. In my theoretical perspective the vast majority of well practiced behavior is accounted for by the standard psychological constructs (scripts, frames, schemata, routines, etc.). My use of subjective expected utility is broader in that subjective decision making is seen to be a more frequent and typical event, in many more contexts (e.g., choices during everyday teaching) than it is in standard economic analyses. Here such events are integrated into the larger frame of decision making[7].

Lampert's (2001) powerful descriptions of the complexity of teaching – e.g., of a teacher's multiple agendas, ranging from dealing (simultaneously!) with short-term issues such as focusing on specific content in today's lesson and a particular student's willingness to risk answering a particular question, to shaping students' personal and intellectual growth over the course of the year – are foundational for any serious description of teaching. Similarly, descriptions of teacher knowledge as reflected in the third (Wittrock, 1986) and fourth (Richardson, 2001) editions of the *Handbook of Research on Teaching* are clearly relevant. Characterizing what teachers know, for example, pedagogical content knowledge as Shulman (1986, 1987) introduced it, and finer taxonomic decompositions of such knowledge for purposes of professional development (e.g., Ball and Bass, 2000), is an important enterprise. However, my

[7] It is worth noting that subjective valuations are a nice way of representing *emotions,* a strong form of orientations. If someone really likes or dislikes something, then the value assigned for to that event for use in subjective expected value computations is a large positive or negative number. Hence the quantifications done in this book represent, in a certain sense, the kinds of emotional, pre-cognitive judgments discussed in the literature (see, e.g., Damasio, 1994, 1999; Lehrer, 2009).

approach differs from that work in fundamental ways. The focus of this book is the issue of *knowledge in use* – the issue of how and why teachers and others draw on various resources as they teach. Whether the knowledge accessed at any given time is subject matter knowledge or pedagogical content knowledge is not of great importance; the key question is why that particular knowledge was accessed and other knowledge was not. For example, I once asked a teacher who presented content to his class in a rather didactic step by step manner (literally: "What is the first step? Good. What is the second step?") if he had ever considered giving the class a problem and letting them struggle with it for a while. He responded, "Not these students. I might do that with honors students, but throwing a problem at these kids would just confuse them." The teacher *had* the relevant knowledge (I saw him act differently in his honors class), but he opted not to employ that knowledge in that context – and that decision made a *big* difference. The focus of this book is on in-the-moment decision making. In that sense, my work is philosophically parallel to work on teachers' agendas and explanations (e.g., Leinhardt, 1993, 2001).

This book adds to the teacher education literature by providing descriptions of the basic mechanisms by which teachers make the choices they make as they teach. It also adds significant generality of theoretical perspective. Although this book focuses on teaching for most of its examples, the theory is about acting "in the moment" in all well practiced knowledge intensive domains. In that sense, it is analogous to my 1985 book *Mathematical Problem Solving.* In that book my explicit claims were about problem solving in mathematics because that was where my expertise lay and where I could present the most compelling examples. At the same time, I believed (and subsequent evidence confirmed) that the framework developed for mathematical problem solving applied to all problem solving domains. In this book my detailed examples are primarily from mathematics teaching (although Chapter 7 does move into the territory of routine medical practice) because that too is my area of expertise. Throughout the book, however, I make heuristic arguments that teaching is but one exemplar of knowledge intensive goal-oriented behavior, and that the theory applies much more broadly.

Finally, I should note explicit differences between the theoretical framing of *Mathematical Problem Solving* and the current book. At the beginning of this chapter I identified the four categories I had found necessary and sufficient for the analysis of success or failure in problem solving: the knowledge base, problem solving strategies, monitoring and self-regulation, and beliefs. I had discussed the four categories separately because, in practical terms, each was very much worthy of attention in its own right. In the 1970s and 1980s heuristic problem solving strategies had not received adequate attention, and they were worth singling out for such attention. The purpose of my problem solving courses was to help students learn to use such strategies, and a major focus of *Mathematical Problem Solving* was to document the fact that students could indeed learn them. For those reasons I focused on them as a separate category. In the larger scheme of things, however, one's knowledge of mathematical facts, procedures and concepts and one's knowledge of problem solving strategies are both parts of one's intellectual resources. In this book they are subsumed under the category of resources (which, in any particular context, also includes the material and social resources at an individual's disposal).

Monitoring and self-regulation remain critically important. Here, however, they are subsumed under decision making. As discussed in this book, decision making includes both unproblematic decisions (e.g., when the individual is implementing standard routines) and more consequential ones such as the "make or break" decisions in problem solving or teaching that rely heavily on monitoring, considering alternatives, and so on.

Goals received little attention in my earlier book, largely because they were an unproblematic construct in mathematical problem solving: after all, when an individual sat down to solve a problem, solving the problem was the goal! (And if the problem was broken into subproblems, those became the focal goals.) But as I moved from studies of mathematical problem solving to studies of tutoring and teaching, goals took on increasing prominence. As noted above, tutors attended to both content and interpersonal issues. The goals to which they gave the highest priorities, whether content-related or interpersonal in character, were a major factor in shaping their tutoring interactions. The role of goals in decision making is a central component of the current work.

Beliefs play much the same focal role that they did in my earlier work. Just as students' beliefs about themselves and about mathematics shape what they do while working on mathematics problems, teachers' beliefs about themselves, about mathematics, about teaching, and about their students shape what they do in the classroom. Consider the example given above regarding the teacher who taught his "regular" students in a didactic manner because he believed that they (as opposed to his honors students) would be "confused" by open-ended situations. Because of the teacher's beliefs about what the students were capable of dealing with, the students were deprived of the opportunity to learn some essential problem solving skills. Hence beliefs are every bit as consequential in mathematics teaching as they are in mathematical problem solving. In each of the main analytic chapters we shall see how they shape the choice of resources.

The term "beliefs" worked well in characterizing problem solving and teaching (and it fit comfortably with the literature's use of the term), but it seemed less apt when I applied the theoretical ideas to other domains. In cooking, tastes and life style preferences are consequential; in other arenas (e.g., health care) one's values play a major role. For that reason I chose *orientations* as an all-encompassing term, to play the same role in general as beliefs do in discussions of mathematical and pedagogical behavior. All told, then, the focal concepts in this book – resources, goals, orientations, and the decision making that entails them – can be seen as the natural evolution and reorganization of the focal terms in *Mathematical Problem Solving.* In addition I hope to show in this book how they all fit together, to explain how and why people make the "in the moment" choices they do.