Co-Evolution of Research and Practice: Lessons Learned from the Learning Progression Modeling Project

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Introduction

The Learning Progression Modeling project is a Learning Progressions project funded through the National Science Foundation. Through this project, the two principal investigators, Richard Lehrer and Leona Schauble, have worked with teachers, a university researcher and professor in ecology from the University of Wisconsin, and their own Vanderbilt University graduate students. This work has taken place over the past five years in two school districts (in two states), to study how teachers create conditions that support students' understanding of science and more specifically, ecology. While the impetus for this project was the development of a "learning progression," what became visibly and overwhelmingly important was the relationship among research, practice, and guided reflection, and how they could be interwoven in such a way that they each supported and depended on the other. This Learning Progressions project is a strong instance of a mutually beneficial and generative approach to research on and development of a learning progression in elementary science that has relied heavily on the ongoing evolution of a cross-grade teacher community.

The emphasis of this report produced by Inverness Research is not the research on and construction of the learning progression itself, but the nature of how these researchers approached their work (e.g., the researchers' work with and the development of a professional learning community among the teachers) and how this work contributed to more thoughtful and effective science instruction and learning. As a result, we describe: the arrangement among researchers, teachers, and students; how the arrangement led to research "findings;" and how teachers' involvement in the research provided scaffolding to transform their practice.

We are primarily interested in portraying how a university-sponsored research program can, if it is carried out in certain ways, create a professional learning community within which:

1) Researchers and practitioners can work together to develop knowledge for teaching that is soundly grounded in both discipline and the learning of discipline, and within which,

2) Teachers can grow as intellectuals and practitioners.

We argue that these two outcomes of university-sponsored formal research programs are both unusual and mutually beneficial.

The majority of this report focuses on the research occurring in Verona, Wisconsin, a close suburb of Madison. The researchers have a history of working in this district, long standing relationships with some of the teachers, and the site has a diverse student body, a very supportive administration, and, over time, the teachers have developed a very strong professional community. Conditions in their other research site—Nashville—were less conducive to supporting the kind of work with the teachers that this research and development approach required. In Nashville, the researchers were able to engage some teachers and assigned two graduate students to work intensely in a few classrooms. However, due to challenges both unique and predictable, progress there has been slower. In this report, we will reference Nashville where appropriate and when it helps to illustrate important supports and barriers to the researchers' approach, which melded research and improvement of practice.

We begin this report by describing the researchers' antecedent work in mathematics and science education and how that experience shaped their work in the LPM project. It is important for the reader to be familiar with the researchers' beliefs about learning and views on the nature of science to contextualize their approach to working with teachers in LPM. Following this background information, we present a framework that Inverness developed to help situate and understand Lehrer and Schauble's approach to research with teachers to support science education. We will describe and provide examples to illustrate each of four key interdependent dimensions: 1) the discipline; 2) "constructs" of the learning progression, 3) teachers' learning and practice, and 4) relationships. Each of these dimensions will be explained as we lead to a discussion of what we call the "fourth space" and how it contributes to the development of a community of practice among the teachers and researchers. The report culminates in an explication of the design principles and key features of the fourth space in which researchers and teachers meet and work together. We see these design principles as the major "lessons learned" from Schauble and Lehrer's work in the LPM project. Through their work in Verona and Nashville, the researchers have learned a great deal regarding the importance of context and how a supportive collaborative space can create productive work and how productive work can further the development of a mutually supportive space. Lehrer and Schauble's work has also demonstrated that where context—work and space—is heavily constrained, research outcomes with teachers, while still important, were less fruitful.

The primary audience for this report is other researchers who wish to work with teachers. However, other readers such as those who make decisions regarding what science education should consist of and how it should be arranged might also find elements of this paper relevant to their work.

Background, History, and Context

A learning progression is supposed to reflect the way that people learn,
not what we want to teach them.

-Leona Schauble

The researchers' perspectives on science education

To adequately describe Schauble and Lehrer's work with teachers and students, and how and why we developed the four dimensions to help describe their approach, we must first explain the researchers' history working in and their perspectives on science education. These researchers are uniquely positioned and highly respected in the fields of mathematics and science education, as they have over 35 years of combined experience working with teachers to help them listen for and understand what children know, and to learn how teachers use that listening to design instruction so that it builds students' understanding in a cumulative, coherent, and comprehensive way.

Schauble and Lehrer's early work, which started over 20 years ago in Verona Wisconsin, a suburb just southwest of Madison, Wisconsin created a strong foundation for the Learning Progression Modeling project (LPM). This work occurred when the researchers were faculty at the University of Wisconsin at Madison and began with Lehrer's project intended to both support and learn about students' understanding of concepts such as quantity, space, measure, and geometry. That project was critical in initiating a small, but very strong group of primary grade teachers in different schools who became leaders in subsequent initiatives to broaden the instructional focus to mathematics and science. These subsequent initiatives blended mathematics and science education by emphasizing the invention and revision of models of natural systems employing the mathematics of space, measure, and chance to characterize these systems. Over time, the researchers' effort spread to most of the schools in the Verona district and involved over 50 teachers in a teaching community that met to discuss students' work, students' thinking, and how to frame students' ideas about the math and science content they were working with. This history is important, as without the initial strong foundation and trust between the researchers and teachers in this community, it is unlikely that the subsequent efforts would have been successful. The researchers created a database that stored evidence of students' and teachers' learning, as well as descriptions of the conditions under which this learning was supported. In components of this work, teachers and students were followed longitudinally across three or more years.

Schauble and Lehrer continuously reviewed the data they collected in Verona after they moved to Vanderbilt University and it ultimately informed their approach on the learning progression modeling project. During the work in Wisconsin, mathematics remained the developmental foundation of the project, and the researchers chose particular science topics specifically "because they afforded model-based investigations that *capitalized* on the mathematics the kids were investigating in the different grades."[1] The new project initiated in Tennessee, on the other hand, was framed primarily as a project in which researchers tracked development of science knowledge. Mathematics remained fundamental in their conception of science, even though they had less direct influence on the mathematics taught in the participating schools. Science, in the researchers' view, is a modeling enterprise, and therefore, science teaching and learning should emphasize the construction, debate, and revision of models of all kinds, including those expressed mathematically.

> *Fundamentally, the question is, 'what should be the nature of science education for kids K-8?' When you look across the sciences, scientists construct models. USE of models is occasionally represented in school*

[1] Personal communication with Schauble.

> *science. But the problem is that school science simply hands students models and expects them to understand the origins of the models. Many students don't even realize what they are learning about are in fact models. Invisible to the learner is the history, the invention, the description, and the mathematics of the model itself. People (and standards documents) have a commitment to science as a collection of facts—it is hard for them to break away from that. We should all have some meta-knowledge of the fact that we are creating and how we use models to derive those facts…. There should be some language and understanding about the fact that we are creating a model—we have representations and not realities that we are operating on.*

The researchers sought to make the development and use of models more explicit and in so doing, support students' and teachers' knowledge and understanding of mathematics and science. At both the Verona and Nashville sites, the research *focus* was on the "long-term development of students' thinking, and the associated professional development of teachers to support students' thinking."[2]

As Lehrer and Schauble see it, science education too often depends on a teacher reciting what some researchers refer to as "final form knowledge." In the rare instances when models are used in education, educators typically simply provide canonical models and ask students to apply them in the solution of problems. Alternatively, Schauble and Lehrer believe that students should generate models as a means of investigating questions of interest, and revise and critique them, rather than working with completed models that are supplied by others. This requires a different stance toward learning and understanding science than is traditionally taken in elementary and secondary science education—it is a stance that more accurately mirrors science as a process of developing and testing models. Early in

[2] Ibid.

the project, Lehrer described how he sees science as a process of interacting with the world and creating models for understanding:

> *What do people do when they do science? "Nature" doesn't just leap out at us—we can't just look out there and see and get "scientific knowledge"—we have to act in certain ways, in relation to what we see, in order to gain understanding.... And we have to develop material means for seeing the world—we have to develop systems of observation, and our ways of seeing are always shaped by ideas that we already have…. As we see things and think about the relationships between them, we might begin to achieve a way of understanding that reaches the status of a model. So, if we believe that the actual process of modeling is important—not just having models—then that has real implications for science instruction.*

Similarly, Schauble said:

> *It is a point of view that says, part of what it means to learn in a domain is to understand how knowledge is made in that domain, and anticipate the making of that knowledge.*

Ultimately and over time, these researchers have pursued lines of inquiry aligned with the idea that traditional, facts-driven approaches to science instruction are limited and ultimately ineffectual: they do not reflect the manner in which scientific knowledge is created and understood, and therefore, they do not help students understand the purposes or processes that motivate the generation of scientific knowledge. As an example, most school systems include the topic of "measurement" as a standard, which teachers typically address at the beginning of the year as a discrete topic and skill, usually focusing on reading a measurement instrument like a thermometer or ruler. In Lehrer and Schauble's view, measurement is a central cornerstone that undergirds all of science, and that having a firm theory of measurement goes well beyond simply manipulating tools. Struggling to measure often changes one's understanding of the construct being measured, and tackling problems of measure is a fundamental component of scientific investigation. Like scientists, students need to address problems of measure, often by generating on their own the measurements that they consider most appropriate for finding answers to their questions. In other words, understanding the nature and process of scientific inquiry, and emphasizing how knowledge is created, negotiated, and revised is fundamental to their perspective on what science education should involve. Lehrer explained:

> *Developing measures of things, arranging for the conditions under which to study things, observing, getting involved with the messiness of defining the nature of the problem, changing your questions, learning from one another, and informing new questions…. These are all things that science is about.*

Schauble and Lehrer believe that a quality science education requires teachers who themselves understand and have experienced the process of developing representations and models, so that they may create opportunities for their students to do the same. Teachers' deeper understanding of and experience with science can help them reveal and accurately interpret students' thinking, respond appropriately by providing challenging and authentic learning experiences, and then build on students' understanding over time. In addition, teachers need opportunities to observe how children think about specific concepts and practices in science, so that their instruction appropriately anticipates students' likely responses to classroom tasks and problems. Lehrer and Schauble sought to better understand what happens when opportunities are created for both teachers and students when science instruction is reoriented around modeling, and furthermore, what contextual factors are necessary for these opportunities to exist.

The researchers' perspective on the role of teachers and context in learning progressions

Lehrer and Schauble have been careful to demonstrate that their conception of a learning progression is not a set of teaching events in any set of conditions. As Schauble said: "It is a model of typical ways that student thinking develops in a conceptual domain, given particular specifications of supporting conditions, especially instruction." The researchers distinguish their approach from others funded under the Learning Progressions program, in that they are more interested in what is possible under varying *conditions of instruction*. Their research did not set out to define a singular learning progression in science to be adopted universally; as a result, they are less interested in developing curriculum devoid of context, since they believe that curriculum and context are inextricably intertwined and, thus, their findings may have limited generalizability to other settings. According to Schauble: "What generalizes is not the specifics of what is taught but a process for ensuring that what is taught builds appropriately on the resources that students have." They are more interested in finding out how to help students develop understanding, and how to support teachers to further students' learning in a particular setting. For them, a learning progression is rooted in students' actual thinking, and requires teachers who understand the domain well enough that they can interpret and contextualize their students' thinking. Hence, curriculum is not the driving force in their vision of science improvement. It is only when teachers see the potential trajectory of each student's understanding and provide opportunities to further that student's learning that powerful learning can take place.

For these researchers, learning progressions happen in real time; they evolve *in situ* and the researchers both promote the development of instruction as well as work closely with teachers and students to inform their research. For Schauble and

Lehrer it is critical that researchers learn how to better help students by studying real instances of teachers working with students in real situations, not in experimental laboratory settings. Therefore, the researchers are attempting to learn how to help students, a few at a time in situ, as a pathway to developing research-based theory. They are trying to develop ways to help teachers create opportunities to illuminate and understand learning progressions through the analysis of students and students' work, rather than by following a specified curriculum that has been laid out in advance. Even though these understandings are being developed in a particular context, the lessons learned can be relevant to other settings, as Lehrer explained:

> *I believe that our results are locally situated, just as ecologies are local, but once having done the local work, there are often more general implications, just as careful study of local systems often has implications for the field called ecology.*

According to Schauble and Lehrer, other learning progression researchers may "hint" at practice, but focus primarily on laying out progressively more sophisticated understandings of an idea. As Schauble said:

> *I think the distinction here is whether the conjectures about development of student thinking are created "top down" (conjectures perhaps informed by research, usually more informed by analysis of the domain) or "bottom up" (that is, constructed on experience of how students actually think about these concepts as observed in situations where people have actually attempted to teach them.)*

Other researchers typically create what they believe to be a learning progression, based on what they think a progression is, rather than spending time with teachers and students to get feedback on what the evolution of learning looks like in real classrooms. Therefore, other researchers are essentially creating an atlas for sequential steps of student understanding. Lehrer and Schauble explain that their work goes beyond creating an atlas, to exploring what long-term change in understanding looks like under particular circumstances of instruction. For them, a learning progression is necessarily context dependent, and evolves out of a negotiation among the teachers, the students, the setting, the materials, and the big ideas of the discipline; and yet, some aspects are generalizable as well.

Lehrer believes that their particular approach to studying learning progressions is unique when compared to most research focused on science learning. He remarked:

> *I think what is probably a signature of our work is that we are trying to understand what the deep structure of the discipline might look like from a kid's point of view, and you can't find that out unless you create a space in classrooms to do that. We believe that this approach to studying science and math instruction may make the disciplines more accessible to kids.*

Schauble and Lehrer are trying to make the foundations of the discipline more visible to students, but also to probe and test those foundations, in the eyes of real teachers and students.

Dimensions of the Research Approach

Drawing on three and a half years of observing teachers' meetings, observing classrooms, and talking with both teachers and researchers, Inverness developed a framework to help understand and communicate Lehrer and Schauble's non-traditional approach toward research, development, and support in science education. Four key interconnecting dimensions comprise this framework:

1) The discipline (specifically the study of ecology within science)
2) The constructs of a learning progression

3) Teachers' learning and practice

4) Relationships

The **Discipline** provides a useful context for advancing students' and teachers' understanding of the nature of science and the role of model-building. Through the researchers' work with teachers around the study of Ecology, they unpack the science discipline in ways that are accessible to teachers and help them see fundamental elements of ecology and more generally how knowledge is constructed in science.

Constructs are tools developed within this project to make the discipline, student thinking, and teacher practices visible. They represent conjectures of how student learning progresses and are constantly changing and being revised, in light of what researchers and teachers learn through their practice about students in classrooms. While the idea of a construct in and of itself is not unique, the researchers' design of the construct is a key contribution of this research, and the formation of these constructs is a product of the researcher-teacher relationship and of the researchers' unique way of doing their work. Constructs are both the focus *and* output of the project.

Teachers' learning and practice (in a community-cultural structure) is where the discipline and constructs are grounded, and where the researchers' and teachers' work together impacts students. In a community where students' ideas are valued and leveraged, the teachers' learning and practices are examined, aimed at elevating students' thinking, and using students' thinking to construct scientific and mathematical arguments (i.e., models in science and conjectures or proofs in mathematics). In this way, teachers serve as true designers of instruction. This dimension illuminates how teachers' practices contribute to the research and also how the process of participating in the research moves teachers to change their practice.

Finally, the **relationships** that develop between and among the teachers and researchers are critical for the ongoing productivity of the research (e.g., the explication and confirmation of the constructs) and the improvement of teachers' practices. In this project, the researchers themselves are community agents, "embedded in their own fly paper," as one researcher described it. Without the willingness of teachers from each grade level to work together on creating an articulated, cross-grade understanding of ecology, this work would not have been possible. Furthermore, without the relationships among the teachers, researchers, and administrators, the space to do this work would be hard fought and difficult to defend.

These interdependent dimensions form a conceptual framework for explicating and understanding the complex work in which the researchers and teachers are engaged together. Together, they show how this project is not just an example of how research influences teachers' learning or how research influences instruction but how teachers' knowledge and practice also influences research in important ways. The following sections explain and illustrate each of these dimensions in greater detail.

1) The Discipline

Schauble and Lehrer have used the study of ecology as an opportunity to explore the nature of science and model development. Ecology is a rich area of study that can be addressed at all grade levels, allows students many entry points, is foundational for understanding evolution, and provides opportunities for local, field-based investigations, in which the project's ecologist is an expert. Because the researchers see the role of the teacher as critical to the conditions of instruction, they assert that teachers must develop their own understanding of ecology in order to provide spaces for students to create, use, and further their own knowledge.

Thinking in terms of modeling provides selection criteria for concepts and topics in the domain worthy of focus. Here, teachers and students target a discipline (ecology) where they can create representations and models, play with them, use them to pose questions, test them, and gain understanding. Lehrer and Schauble emphasize those ideas that teachers and students can steadily and progressively build upon, making and using models that expand in power—instead of coming to an "end of understanding." In a paper written by Schauble and Lehrer in 2007, they describe their view of how developing, using, and revising ideas and models are essential components of science and too often overlooked in school science:

> *The instructional materials and activities that the researchers and the teachers develop and adapt are designed to incorporate aspects of scientific practice, which they consider essential for students to engage in. These include involving students in all aspects of scientific investigation, from question posing to identifying relevant features and attributes; to developing, revising, and sharing measures; as well as collecting, structuring, and representing data; weighing alternative interpretations; and persuading others. In much of school science, students collect data but have little opportunity to pose questions or to wrestle with ways of arranging the physical world so that it can be studied. Even in classrooms where students do investigations, the questions usually come from teachers or developers, and the materials are usually provided beforehand. Much of science involves figuring out how to get the world to talk to you by arranging instruments and apparatus that can deliver interpretable information, and students can learn a good deal of science and about the nature of science by participating in these struggles. We focus at all grades on the*

development of meta-representational competence, because representations (including mathematics) are important resources for the developing of modeling. Students are repeatedly encouraged to invent representational solutions to problems and then to consider what the variety of inventions "show and hide" about the issue at hand. (AERA LP Symposium 26 March 07).

To probe the discipline more thoroughly, Lehrer and Schauble recruited an ecologist from UW Madison to help them identify topics fruitful for exploration with teachers and students. Importantly, they wanted the teachers to be able to design activities that were centered on local spaces (a pond, a forest, a stream) rich with potential questions for students to investigate. The ecologist provided the disciplinary expertise to help guide teachers (and in turn, students) in building models and thus developing their understanding of the ecology of the local areas in which they were working.

With help from Schauble and Lehrer, teachers designed and conducted investigations in the field and classrooms (e.g., why are there more cattails on one end of the pond? What happens underneath the ice in the winter?). They drew on their students' questions about the local spaces to raise questions that would help the students uncover the discipline. One kindergarten teacher explained how these field-based experiences with the researchers and ecologist have changed her ideas about science teaching. They have allowed her to anchor her instruction on some key unifying concepts in the discipline (e.g., structure, function, needs, behavior) while simultaneously responding to students' interests. She said:

Before my involvement in this project, science would have been one or two little experiments. I can't tell you that we would have gone out to look at a tree outside. I think I would have read some books about trees and we would have drawn trees without going outside to touch them *and smell them and look at them and observe them over the seasons. We didn't have clarity about the concepts we were going to teach. Now when we are talking about fish, we talk about the fact that they have structures, and they have basic needs, and their behavior is influenced by their environment. That attention to detail was never there before, and it is now.*

Also, science now is open ended. Maybe I could have said before that I taught from children's interests, but I don't think I did, not truly, and now when you see something happening in your room and you see that students get excited about seeing something and making observations, and you are recording those observations and then you are asking them questions about those observations… that's what drives your instruction. Before it was, 'this is the unit we teachers are doing, let's open the box and let's decide what papers we need, and plot it out'. Now, we as teachers look at the concepts and we start our investigations with hands-on things to do. It is so much more hands-on, and it is so much more developmentally appropriate and it is so much more about observation and attention to the development of a science language.

Reflected in the comment above, and heard from several other teachers in interviews and in meetings, is a significant shift in teachers' perspectives on the role of questions and representations in science. Rather than simply following the definitions and directions in their curriculum kits, teachers' evolved a broader and more complex view of the nature of the science discipline. Teachers emphasized following student thinking and questions when appropriate, and allowing students to invent ways to best represent their observations, and then defend their choices. One teacher commented:

Teaching science is providing opportunities for students to ask questions and seek out responses, and be actively engaged in their learning of something that is ongoing, and not necessarily part of a boxed curriculum. With a boxed curriculum, students do an experiment, get an answer, write something down, and move onto the next thing.

Another key focus for the teachers was the understanding of "big ideas" or unifying concepts in the discipline, steering away from discrete topics or concepts, such as "trees" toward putting topics and concepts in a larger context. One teacher of a combined first and second grade class described their process:

We began with some very good looks at what are some big ideas in biological science that are really important for us to understand as teachers. Then, we looked at how we could take some of these big ideas, and the kinds of opportunities that we could provide for kids to understand these big ideas. We asked ourselves, what are some in-class models that we can use and what is the environment outside that we can use to help get at this understanding of big ideas?

Through their work with the researchers and the ecologist on the project, the teachers came to see the discipline of science—and teaching science—differently. Teachers' own experiences conducting investigations in the field and in the classroom, and creating and using their own models to understand ecology provided them with the conceptual base and confidence to open their instructional practice with students in science. Teachers often referred to the constructs, discussed below, as a critical guide for what constitutes a big idea, how to develop student understanding of that big idea, and what instructional models might support students' learning.

Thus, ecology as an area of study allowed the researchers and teachers to learn how students come to understand the ways in which science works, i.e., the nature of developing and testing ideas that explain natural phenomena. To understand what the deep structure of science looks like through students' eyes is a big goal of this research. This approach to the discipline is, in and of itself, advanced by the other dimensions, described next.

2) Constructs

As noted above, constructs are both a focus and goal of Schauble and Lehrers' research. Constructs are best described as a kind of map within which teachers can locate their students' current state of understanding big ideas, and plan for the next stages of their development. Through their work with teachers and the data researchers gather from the teachers and their students (student work, student journals, teacher-created assignments and assessments), the researchers continually refine the constructs. Researchers look at the student work, in some cases along with the teachers, they observe teachers practice, and they work with teachers closely in monthly meetings. They take careful notes, interview teachers, and rely on knowledge they've gained from other contexts as well, to refine the constructs.

While Schauble and Lehrer have created constructs in different areas of study within science, the one they used most often with teachers was the Ecology construct – or as teachers began to refer to it, the "Eco construct" (see Appendix for the Ecology construct, now referred to as the Ecosystem Construct, which has narrowed the focus). In the Eco Construct, a level 1 understanding might be "*Initial criteria for life are based on overt resemblances to familiar organisms, especially people. Initial criteria for habitat are based on analogy to home*." A level 3 understanding might be: "*Relate organism to habitat via organism's needs and ways of satisfying those needs. The relationship is perceived to be unidirectional: The habitat satisfies needs*." (Lehrer and Schauble, 2010).

Based initially to some degree on the researchers' prior experience and wisdom, constructs are concrete artifacts that bridge the discipline, teachers' practices, and student learning, in the sense that they provide a focal point or a measure against which to assess students' understanding. However, as Schauble notes:

> *Constructs are models and capture what is most typical. Therefore, they are not intended to assess the understanding of individual students. Any student is going to show variability, both within and between tasks.*

Constructs are also dynamic, they are conjectures about the progression of student learning (which is not necessarily a linear or step-wise progression) and are constantly being revised as teachers' work both draws from and informs them. Constructs are different from standards in that they are not pre-ordained, rather they evolve out of experience and reflection; they are dynamic; and they are negotiated through the interaction of the discipline, the classroom, and the students' own understanding.

The constructs can also function as the teachers' guide or "instructional north star." One teacher explained how the ecology construct has been used by the Verona teacher community:

> *The researchers would help us draw out the big ideas and then we would look on the ecology construct map and see how they fit into that, and then we would revise the plans and move forward. Then the following month we always came back and shared: 'What did you try?' 'What looked different this time?' and it was really fun to see the different approaches that everybody tried. Someone might bring a chart that they developed with their class and someone else might bring journal entries and another person might bring some non-fiction*

writing. We could see what were the common pieces and where they fit on the construct map.

In meetings, teachers would gather in grade-alike groups, and with their lesson plans and constructs out on the table, determine where in their unit the ideas in the construct appear, and what have they learned from their students that could inform the constructs.

The work with constructs has been useful to teachers outside of project meetings as well. One third grade teacher describes how she and her colleagues refer to them in their instructional planning:

> *[One teacher] will bring me student journals and say 'look at this, look at what they are saying here'. And then she will turn back some pages and say, 'this is what they were thinking, and now this is what I did to get them there'. I think that is really powerful, and I am seeing that happening a lot. I am watching in kindergarten, really listening to what kids are saying, and interviewing and questioning what they are doing. I am thinking about what we are doing in first and second grade too…. I think that has been very powerful.*

Over time at both the Verona and Nashville sites, the teachers began to use the constructs and consider them in their everyday planning for instruction. Teachers refer to the constructs as "maps," "guides," "tools," or "benchmarks" for helping them plan their ecology instruction. They provide a "starting point" for some teachers.

It is worth noting that Schauble and Lehrer's approach to researching a learning progression goes beyond simply creating this map and handing it to the teachers. Rather, it is important for the teachers to see that the constructs evolve as they are used, and teachers provide input into the evolution of constructs, based on the experiences they have with their students. Thus, teachers know that what they learn from their students will inform the constructs, that it is an evolving and dynamic document. Teachers' evolving understanding of the discipline and their iterative use of the constructs contributed to major changes in their teaching practice, described below.

3) Teachers' Learning and Practices

Lehrer and Schauble's work with the teachers in Verona provided scaffolding that enabled the teachers to learn from discussions with the researchers, their own practice, their students' thinking, and work with each other. These teachers are not using a scripted curriculum or teaching discrete topics or activities—they are guided by the evolving construct map, what they are hearing and seeing from their students, and what they are sharing and learning in the monthly and weekly meetings with other members of the professional community, including the researchers. Their practice in ecology is driven by student questions and discourse, and making sense of student thinking through talking with their teacher peers. Their practice is always guided at a meta-level by the constructs, which provide a framework, a touchstone, for designing and reflecting on instruction.

Importantly, Schauble and Lehrer believe that most research purporting to engage teachers, treats them more like "shop managers" than professionals. In contrast, their own work with teachers reflects their profound respect for teachers and teachers' professional judgment. In Verona, a lead teacher who worked with Schauble and Lehrer on her Masters degree over 15 years ago, and participated in their original work about geometry and space, facilitates and supports the teacher community and helps plan monthly, five-hour Saturday meetings among the teachers involved in the work, a university ecologist, and the researchers, who fly north from Tennessee to attend. The teachers include those from three different elementary schools, one middle school, and one high school. The teachers themselves facilitate these meetings, which are opportunities for the teachers to share examples of their teaching practice and their students' work (in the form of paper assignments, project work, field work, photos, video, journal entries, etc.), and explore the relationships between the discipline, the constructs, their students' thinking, and their instructional practice. These meetings also provide an opportunity for the researchers to test their assumptions about learning and teaching and to introduce new concepts, tools, and resources to the teachers. During meetings, the researchers and ecologist might ask the teachers a few key or provocative questions and provide their perspective on students' thinking, but for the most part, they listen to the teachers work together without interference. It is a highly collaborative atmosphere and over the years of their work together, the teachers have grown to treat the researchers and ecologist as other members of the community—albeit members with a different, more external, and perhaps fresher perspective.

The Verona teachers also meet independently of the researchers frequently (formally as well as informally), sometimes to follow up on the Saturday meetings, other times to address a particular issue they are all interested in, such as using journals in their science teaching. The kindergarten team leader told us:

> *Each month we would have a topic that we were going to address and we always brought out that eco construct map when it was a topic that was about something living. So we were trying to tie what we were doing to the eco construct map.*

Teachers' learning and practice are critical to the research in this endeavor. The teachers in Verona have developed their knowledge of ecology and approaches to teaching it that are informed by essential elements of the discipline and their students' ways of thinking. The teachers are key informants in helping the researchers add flesh to the bones of the researchers' ideas of what a learning progression in ecology might look like for their grade levels and classrooms. The researchers describe their work with teachers as a two-step process: one is carving out and testing an idea that the researchers have in terms of what might work with students, and two is capturing or recording the ways that teachers can access and build upon it.

> *We say, these are the big ideas and we are trying to figure out how kids think about them, and here are some initial ideas. Now let's go find out if this is how kids really think about them. We talk about that as a group, and then in part, the learning progression emerges during the conversations with the group, because then we know what it means to the teachers and students.*

The lead teacher of the Verona group acknowledged that the researchers' approach to working with teachers could be disconcerting to most teachers, because clear, easy answers are not always obvious—they have to figure them out with one another and their students. She explains:

> *[Working with Lehrer and Schauble] is very different. We don't have somebody coming in with a finished product saying, 'we have developed and tested this curriculum…. This is really effective, try it in your classroom and see how it goes. Then we don't want any feedback from you by the way, because we have already marketed this and we are good to go.' Help for teachers usually comes in the form of something that is already done, and you as the teacher are supposed to try it out. Here we are part of a project where we all don't know. We don't know all of the answers. The researchers will say that, and for some people, that is disconcerting. And for other people, it is exciting. So depending upon the type of person you are, this can be a very effective approach…. I think it is very different in that regard. It is also very different in the sense that they are unbelievably supportive of you wanting to try something new, and they are*

> *providing opportunities and materials for you to be able to do that. That is really remarkable, and that is not something that you ever get. You typically get, here is the box and this is the materials that you have got, as opposed to, this is what I am thinking of doing, what do you think about this? They helped to make that happen and that is very unusual.*

A third grade teacher described her experience in the Saturday meetings working with the researchers:

> *On Saturdays we come together and we share with other teachers our student work and we also share with them our struggles and our concerns and our next steps. We go through a process of talking about what we could have done, what might work better, but also, there is a lot of self-reflecting, and then Leona and Rich probe us with more questions. I think that they are really, really talented and gifted at getting a teacher to really think about their practice through their questioning, and making you think about what has gone well and where there are areas that you can make improvements. It is never a judgmental thing; it is always helping you to push your practice to the next level. I think they are a fantastic resource. I have bounced ideas off of them… and they are very willing to help us move our practice forward and to move our students' scientific and mathematical thinking in a different direction, where it is just not black and white, but it is okay that there are shades of gray.*

In interviews, several teachers mentioned their initial discomfort with not knowing if they were doing it "right," or if the kind of student work they were collecting to inform the constructs was useful. However, over time, as they gained more experience working together and with the researchers, their confidence grew and they became more comfortable with not knowing the answers *a priori*. This is true for both their meetings and the classroom work—they had to open up their practice, and be flexible enough to allow students' questions lead. One teacher describes her experience:

> *The researchers don't have a set agenda of what they're looking for from me. That was a really hard place to come to. Because it is not the way things work usually. Usually when you are doing something, and unless you are a researcher you are thinking, I have an assignment, and what is my assignment, what is the end goal? But that is not what this is. So that lack of concrete assignment has become clearer to me and I am more comfortable with that. It is okay that I don't have all of the answers and it is okay that they don't have answers and it is okay that I don't really know what they expect, because they don't really have an expectation of what I was going to produce. They just have wonderings and questions.*

Despite some discomfort and uncertainty, in interviews and in meetings, we heard numerous examples of ways teachers incorporated what they were learning in their teaching. One kindergarten teacher described how documenting her student thinking with a video camera helped her think of ways she could push their thinking further:

> *It was effective when I would video tape them. I would ask questions and things would just come to me, wow, this is the way they are thinking, what can I do to make them think deeper? Okay, they are thinking that these fish are dying because it is too cold in there. Well, they could be right or they could be wrong, and I don't know the answer, but we just better keep going with this and keep track of the temperature of the water, and we better explore other things that might be going wrong with the water. We could contact the fish store and ask them questions, and find out that you do not put 20 fish in a fishpond, because they emit nitrates in the water, and the water gets poisoned and then you have dead fish. I was learning right along with them.*

For another example, a third grade teacher working on a pond study with her students wanted to design an experience that would enable them to see the seasonal environmental changes at the pond, and also to be able to document how students' questions change over time. She took her students to study the pond in the fall and spring, and noticed that students did not observe much change in the vegetation or wildlife. She wondered: What if we went to the pond in the dead of winter? What might the students observe then? She worked with two other teachers, one of whom worked with bilingual children, and planned for a winter pond excursion. The teachers quickly realized that they could not get very far in their planning without knowing their students' predictions, or their questions about the pond in winter. She described what happened next:

> *We have the questions broken up between plants, animals and water. Those are our 3 categories, and we have questions in all 3 categories. We sent these questions on to Robert (the ecologist) to say help, what do we do? Robert has been very good, just like Rich and Leona are, about saying, okay, the way I see it, you need to find out from them how they are going to measure this, and how they are going to study that? Pushing us once again, not giving us the answer, but pushing us and guiding us into having these conversations with the kids. We sent a list of like 20 or 25 questions to Robert that the kids had generated, that we felt were pretty legitimate questions coming from 3rd graders…. One of the things that the kids want to do is collect sediments off the bottom of the pond and see if they can find any evidence of insect life. They are thinking that they are going to find frogs that have been hibernating and they think they are going to find dragonfly and damselfly nymphs that are in the mud. They are banking on it. They are so excited. So, that is one of the things that they really want to know about and they also were interested in the thickness of the ice and the layering of the ice and they wanted to know about temperature at different depths of the pond, and they want to know how deep the pond is.*

This kind of working with students did not happen for this teacher prior to engaging in this research project. The teacher commented further:

> *That is what I think is so incredibly empowering about this project—just when you think you have got it, you push yourself to the next level. You say, well, really, what we want is a profile of what the kids thought about this one area over time. To do that, we really felt like we had to add a winter piece into this, because they needed to see the pond in a completely transformed state and the only way you are going to see that is if you go in the winter. So, we just feel like this is a really great opportunity to show evidence of their thinking and their progression of their thoughts about one area over time. Pretty cool.*

The teachers ability and propensity to work in this way, i.e., to collaborate with one another, and seek advice and knowledge from experts in the field, was made possible by the relationships that were forged and nurtured throughout the project, described next.

4) Relationships

The role the researchers play, and their relationships with the people and the systems they are studying are unique and critical to the work. How the researchers became involved and embedded in this community over time is a key dimension, as are the relationships teachers have with one another and the relationships with the surrounding context of the local educational system. One teacher, asked to describe the collaboration between Verona School District and Vanderbilt said in summary form:

We collaborate in order to move our collective thinking forward about science and mathematics learning and teaching.

A teacher leader described how the community is inclusive of teachers with different experiences and how they enjoy learning from one another:

That was everybody's favorite part – when we got to share and learn from each other and move forward as a whole group. It was a bit of a challenge because I had been with the project the longest, and then we brought a few more teachers on, and then this year we brought a few more on and it was like we were at different stages. We could see that reflected in the teachers' journal entries and their progression. You know the first year you try something and then the second time you refine it, and you get a feel for how to get more in-depth answers from the kids.

Teachers typically worked in grade-alike groups for at least part of the monthly meetings. Each group approached the work somewhat differently, but all with the goal of sharing and discussing their teaching and what they are finding out about their students. Providing the opportunity for the grade levels to see and hear their work, and how the thinking of the students is evolving over the grade levels is a key piece of the sharing and learning. Describing how teachers work together, one teacher said:

At the end of one meeting, we brainstorm what the next meeting should be about and what we need to cover and then I send out a draft plan and they give me feedback and we go from there. Of course this is all very flexible because we may or may not have as much time as we think we will on a Saturday. But everybody works together to produce the artifacts for Rich and Leona. Then two people might pick the charts and *go work on them together, and two people might take the journals and check out real quick what they notice about a top learner, a middle learner and a low learner, etc. I think just by pairing up like that, we learn a lot from each other*

The benefits are that we brainstorm together and we come up with the ideas together. I always feel like when I have another person or a group to talk to, my ideas become refined as we have conversations, and so talking about the big ideas and what we hope to get our students to achieve really comes out through that collaboration. The sharing of work is another big benefit because another teacher shared some story writing that she did with her students and it gave ideas to the rest of us.

The meetings provide an opportunity for the researchers and teachers to sit across the table from one another and explore the work in more depth. Teachers share their students' work, or other artifacts of their classroom practice, and the researchers comment, ask probing questions, or make suggestions for next steps. When we asked for an example of the researchers' relationship with the teachers, one teacher said:

Let me tell you about our last meeting. [Schauble] was sitting in on our meeting and we were doing our sharing session, and she took pictures of the charts that we had and then she read over the write-ups that we did for the pieces that we were handing her and she would comment on them, like 'this is really interesting'… and 'how did you go about that?'… and 'wow, you used great questioning to get there.' That was neat, just to have her sit there and have a conversation with us. That is probably the most valuable thing that we get [from the relationship] but we also have email conversations too and so generally at the end of the session, we will be thinking about what we need in order to make the next unit *happen…. I will coordinate the teachers and have conversations with Leona, Rich, and Robert until we get it all figured out.*

School and district administrators are also relevant players in the relationship dimension, since their support is essential for this work to take place. One teacher described her principal's interaction with the project:

Our principal has certainly been in the room to see what we are working on and what we are doing and she's interested in how the project is helping us. She comes in (randomly at times) and visits and so she sees what is happening, too…. I think she really appreciates the fact that we have the grade level conversations and we're able to do that so that any child leaving a certain grade has had a common experience.

One relationship in particular that proved critical to the ongoing success of the project was that of the teacher leader to others in the project. Her primary role was as a liaison to the researchers, the ecology expert, the administration, and eventually other schools and teachers in the district. Importantly, she kept abreast of what the other teachers in the project were doing with their students maintaining a birds-eye view of the project overall. She scheduled meetings, kept teachers informed of project developments through regular emails, ordered supplies, arranged field trips, reminded teachers to bring certain documents to the meeting and to post on a website, and many other logistical tasks. Of her role in the project, Leona commented:

The mighty efforts of exceptional individuals are always important too. The teachers would be very much the same teachers if they didn't have someone like [the teacher leader] running behind them to say, have you written your thing for the website, and we would really like to see this thing that you did.

Finally, one teacher described the influence which the project and the relationships that have developed have had on her students' overall achievement, as she reflected on her three years of involvement with the project:

> *Just looking at where I have come as a science teacher in 3 years has been pretty remarkable… and how I didn't really like science in the beginning and science was maybe more fluff in kindergarten, and you might make an art project of a fish. So [the project] has helped me enjoy teaching science and know what to look for in the student learning and be able to move children in a future direction. It has had a huge impact, not only in science, but I see this in literacy also. Our district doesn't really keep data on the science concepts as much as they do on the literacy end of it, so while I can't say '80% of the children have moved in this science concept', I can say that '95% of the children are proficient in reading and probably 45% of them are considered advanced'. So there are data that reflect the students' achievement, and that has happened in part because of the science project.*

These four dimensions—the discipline, the constructs, the teachers' learning and practice, and the relationships that developed—while each critical in their own right, also contribute strongly to the formation of a unique, arranged, and negotiated professional learning community. That is, the research work was made possible because the teachers were willing and able to engage in teaching the discipline in ways that provided useful information about student learning trajectories, which in turn required developing and nurturing the trusted relationships among all of the participants as they collaboratively developed their practice and shared their experiences and ideas. As noted earlier, the work both created and was formed by the space that was made available for these teachers and researchers to work together. In the next section, we examine more closely the development of this space, or community of practice, and why it mattered to the research taking place there. While each of the four dimensions we've described above is critical in its own right, together they form a unique kind of arranged, negotiated community of practice, and a unique approach to improving science teaching.

Developing a community of practice: The "fourth space"

Through their intense work together over the last four years (in addition to their longstanding work from 15+ years ago) the now nearly 30 teachers, along with the learning researchers and ecologist, have a shared purpose, language, and set of practices that are productive in this Verona community. Over time, the work of the teachers and researchers has been both created and supported by a "fourth space:" the physical, political, intellectual, and practical room for teachers and researchers to explore student learning and try new practices that support it and advance it. This space has evolved through iterative examination of student work and student thinking, which the teachers have learned to make more visible. We argue that while the characteristics of the situation in Verona are special, they have a larger message that is more generalizable and of value for other researchers who wish to work with teachers. What Schauble and Lehrer have accomplished in Verona is the cultivation of a community on a local level, based on deep principles and structures. This "fourth space" serves as a model of moving "research to practice" (and also translating "practice into research"). The lessons learned creating and defending this "fourth space" are of value to other researchers interested in accomplishing similar goals. This is not a boutique situation that is irrelevant to the rest of the world. It is indeed a powerful case that illustrates what it takes to create such a space. The following section explains how the four dimensions described above must exist together within what we are calling a "fourth space."

One teacher described how the community's inquiry into the science discipline, in combination with the relationships and constructs that the research has contributed, has led to the creation of a space for teacher learning:

> *It has opened up communication so that if somebody is really excited and learned something new, they are dying to tell the rest of us. Putting things on the [ecology] construct map just makes you more eager to tell your colleague.*

In the creation and defense of this space, all participants have a key role: teachers take risks by trying new approaches, and testing the limits of their own practice and content knowledge, and they contribute to their own and others' teaching by providing insight to the research and the refinement of the constructs; researchers bring learning sciences knowledge and experience, and feedback on teachers' ideas and interpretations of student work; and scientists bring content knowledge and background information about the concepts being explored in a "just-in-time" fashion. Teachers are supported in an exploration of the "deep structure" of the discipline and the nature of scientific knowledge. They collaborate in developing, testing, and revising the constructs that guide the researchers and the practitioners. Researchers encourage teachers to provide opportunities for students to invent methods for finding out, for measuring, for drawing conclusions, for asking questions—for doing science.

A teacher who was relatively new to the work explained the experience:

> *It is like nothing I have ever had before, the hands-on nature, the collaboration, the permission to take risks and just the nudging of the thinking about science. I have to be honest, I haven't sought out a lot of science professional development because it was just not that exciting to me, but this… definitely, as I said, my attitude changed drastically and*

being around the group for a couple of days and experiencing the excitement and the interest. It truly is like nothing and no professional development that I have ever been part of… and I so appreciate the collaboration.

While some teachers and other researchers might be inclined to consider this fourth space another form of professional development, it is beyond that. One teacher said:

This project is very different from other kinds of professional development. We don't have somebody coming in with a finished product saying: "We tried this. This is really effective; try it in your classroom and see how it goes. We are part of a project where we don't know. We don't know all of the answers—the researchers will say that, and for some people, that is disconcerting I think. And for other people, that is exciting. It is also very different in the sense that the researchers are unbelievably supportive of you wanting to try something new and they are providing opportunities and materials for you to be able to do that. That is really remarkable and that is not something that you ever get otherwise.

One of the principals in Verona has been instrumental in supporting this fourth space. She sees the potential of the arrangement:

[The teachers] know the students, and they know what they are trying to teach…. The interaction with Rich and Leona and the scientist, along with the collaboration of the grade levels , K-5… and having our reading resource and technology people be part of it… it seems like they really have a broad sense of the child's entire day. They have really done a nice job of combining all of those parts together. I think it is a very safe learning environment, just like we try to provide for the students.

In many ways, this work in Verona is consistent with descriptions of a *community of practice* found in the literature. In a recent paper, Etienne Wenger articulates the components of a community of practice (Wenger, 2010). According to Wenger, a community of practice includes the following elements:

- "The domain: members are brought together by a learning need they share (whether this shared learning need is explicit or not and whether learning is the motivation for their coming together or a by-product of it)
- The community: their collective learning becomes a bond among them over time (experienced in various ways and thus not a source of homogeneity)
- The practice: their interactions produce resources that affect their practice (whether they engage in actual practice together or separately)" (Wenger, 2010)

In education, approaches to professional development do not always include opportunities for teachers to participate in a true community focused on a shared learning need that results in new practices or resources. This kind of arrangement is especially rare over an extended period of time. We are arguing in this paper that these opportunities wherein researchers and teachers truly collaborate in authentic ways—each learning from the other—can inform and improve science education, not just in one classroom, but also in resources that benefit the larger field, as a whole. In Verona, the work of the teacher community over the last four years has been focused on co-developing and understanding the landscape over which teachers and students progress in their understanding of ecology and the nature of science. Over time, the teachers, learning researchers, and ecologist have developed a shared language, tools, and resources, with which to explore and probe the foundations of the discipline itself. They have negotiated and continue to negotiate meaning through the use of the construct—and to operationalize it. The community as a whole is devoted to exploring ways to encourage children to ask their own questions of ecological phenomena, and invent ways to answer their questions—all guided by teachers who have enough knowledge of the discipline and knowledge of student thinking to move them forward.

In their meetings together, teachers work intensively on developing classroom experiences that draw upon their students' thinking and the structure of the discipline, with input from the learning researchers and the scientists. These experiences are tried out in the classroom or in the field, sometimes with the learning researchers present. Examples of student work are collected and discussed at subsequent meetings, and instructional approaches are critiqued and refined. Much of the students' and teachers' work is documented and shared on a website, where other teachers in the community can access it and share in the reflection. The knowledge generated from this process informs the learning progression (constructs) the researchers are trying to articulate, and the learning progression in turn informs the teachers' conversations, planning, and practice. The collective and shared focus of developing constructs from theory and real experience is what makes this community unique, and provides a common mission.

Over the last four years, this process has created an arranged, negotiated space that authentically integrates research and practice, as well as a different vision of the roles of the teacher and the researcher—both in the classroom and as part of an educational research endeavor. In LPM, all of the participants are critical for this work to happen—the teachers co-create the constructs through their practice and reflections on their practice. They are gaining knowledge of, interest in, and confidence to teach science. They are leading a change in their district that provides a quite alternative view of science education and teacher leadership.

The researchers are also critical participants of course, in that they contribute to teachers' knowledge of science, science teaching, and students' learning and development. They draw on what teachers do, say, and think about student learning to inform and instantiate their theoretical work. In many ways, the researchers' methods for working with teachers parallel those they advocate for teachers using with their students (i.e., asking questions, making conjectures, collecting and documenting data, etc.). Without the key feature of this fourth space—the collective desire to find and define patterns of development and articulate learning across grade levels—the constructs would not exist. In other words, the cross-grade community is essential for making the development of a construct possible.

Design Principles and Key Features of the Fourth Space
and
Lessons Learned Regarding the Process of Coevolving a Learning Progression

This project is a strong instance of a mutually beneficial and generative approach to research on and development of a learning progression in elementary science that relied heavily on the ongoing evolution of a cross-grade teacher community. Here we outline some of the key lessons learned from this particular approach to simultaneously studying and creating a learning progression.

- *Improved instructional practice evolves out of intense, ongoing, and iterative examination of students' work and students' responses to instruction in the context of essential ideas of the discipline.*

Features that support this work include but are not limited to: projects that are field-based, or simulated inside the classroom; curricula/instructional materials that are developed collaboratively with grade-level teachers and Learning Progression researchers and staff; teachers who listen to what students say and do to guide instruction; and teachers who implement a variety of formative assessment practices to guide their instruction

- *Forward progress depends on ongoing negotiation of students' authentic questions, teachers' constraints and limitations, and researcher goals.*

Features that support this component of work include teachers who are willing to open up their practice, share their students' work, and make meaning of students' questions with each other and with the researchers.

- *Research and professional development are dependent on and grounded in classroom practice and the shared task of constructing a learning progression K – 8.*

Features that support this aspect of the work include: teachers who bring examples of student work and questions about their instructional strategies to the group to discuss; researchers who bring a perspective on students' cognitive development and expand teachers' thinking; an ecologist who brings a perspective on the science content and alternative ways of representing concepts at different levels of understanding and helps develop learning opportunities; and teachers and researchers who co-evolve levels of understanding that result in the development and evolution of constructs.

- *Curriculum emerges from teachers' work together, students' questions, and researcher suggestions. Constructs help frame how concepts are approached at each grade level, and are evolving.*

Key features that support this work include: students' and teachers' questions about the topic or concept leading to more in-depth investigations; researchers playing a large role in guiding curricular decision-making (based on vast experience and knowledge of science and math teaching in elementary grades); grade level teams working collaboratively to develop concepts and activities; teachers working across grade levels to understand what is appropriate for students to learn at different ages and how to prepare them for future learning (vertical alignment).

- *Constructs inform the work that teachers do, and the work teachers do informs the constructs.*

This reciprocity is identifiable when: each professional development activity is guided by teachers' current interaction with the constructs; the constructs are the key outcome of the research project; the constructs are based on researchers experience and informed by teachers experience and input; teachers illustrate constructs by providing real examples from the classroom; and teachers pay close attention to student thinking and learning and bring examples of student learning, as well as reflections on the instructional sequences that lead to advancing learning.

- *Researchers became an integral part of the teacher community, helping teachers focus on student thinking, suggesting instructional strategies, and bringing science content when needed. Importantly, the researchers pushed teachers to question traditional practices and approaches to teaching ecology topics.*

The description above may sound familiar to many as just another example of an inquiry approach, or a learning community or an inquiry community of practice. Indeed it shares many of those characteristics. What sets it apart is the symbiotic relationship between researchers and practitioners. The arrangement established by LPM allowed for a "win-win" arrangement that provided deep professional development for teachers, improvement of instruction through practitioner inquiry, and rich research findings—in the form of the constructs, the knowledge that underlies them, and their use—that emerge from authentic *in situ* work. The emphasis on the big ideas of the discipline and the shared, co-created constructs makes this a strongly focused community. Perhaps this is the biggest lesson of LPM: that researchers, scientists, and teachers can work together in real time and real places to generate knowledge and improve practice in a singular coherent effort. Having researchers integrated into the work of schools, having teachers thinking about the same questions that researchers are thinking about, and having all of this happen in an integrated, real-time, back-and-forth mode of work—all of these provide for an interesting and fruitful "research to practice" model. This approach, however, is not for the timid for it requires a substantial shift in modes of work for both researchers and teachers as well as a willingness to make the effort to create and maintain the space for this work to occur.

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