Accumulating Knowledge on Elementary Science Specialists: A Strategy for Building Conceptual Clarity and Sharing Findings

This article offers a framework for supporting identifying and organizing the elements that comprise elementary science specialist models. With these first building blocks, it is the hope of the author to create a foundation for shared language, conceptual understanding and accumulating knowledge about how to bring high quality science education to elementary schools.

Scientists and educators have argued for inclusion of science in the school curriculum from the earliest years of our public education system. In the mid-1800s, Edward Livingston Youmans suggested that science was the best means of contributing to both "useful knowledge" and "improved mental power" (Deboer, p. 6). Later in the century, Thomas Huxley made the case that science study should be part of schooling as early as possible and that it should focus on direct observation and study of natural phenomena (Deboer, p. 10). The calls that they and other scientists made for inclusion of science in the curriculum focused on student-oriented experiences that engage students in authentic practices of science; a very different type of science education from what we typically find in today's schools.

Distinguished educators have agreed. Nearly 100 years ago in *Democracy and Education*, John Dewey wrote "… by following, in connection with methods selected from the material of ordinary acquaintance, the methods by which scientific men have reached their perfected knowledge [the student] gains independent power to deal with material within his range, and avoids the mental confusion and intellectual distaste attendant upon studying matter whose meaning is only symbolic" (Dewey, 1916, p. 221). And Charles Eliot, the head of the Committee of Ten suggested that science was an effective way to develop mental abilities and should be taught with "objects and instruments in hand" (Eliot in DeBoer, p. 30). Continuing into the 20th Century, Joseph J. Schwab a scientist-educator from the University of Chicago, suggested that science would be a means for teaching students to actively engage in a process of analysis, look for evidence, and validate their own findings (Schwab, 1962).

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Unfortunately, there is yet to be a time when these distinguished individuals and others who advocated for the merits of science education would see their positions widely realized in our schools. Elementary science education has enjoyed increased popularity in some settings during isolated pockets of time, but it has not yet made the shift from passing trend to accepted regular practice throughout our country. The closest our nation has come accompanied the watershed event of Sputnik. This 1957 moment of perceived defeat sparked an unprecedented commit-

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ment to science education in the United States. In the years immediately following, the federal government invested in curriculum programs that engaged children in "doing science" and at their peak, nearly half of school districts surveyed used one of them at the elementary level. Eventually however, their popularity, once driven by a focus on scientific disciplines and the United States' desire to develop more scientists, waned in the face of newly emerging priorities for science education such as scientific literacy, environmental education, and the role of science in society (DeBoer, 1991).

Debates about the purposes of science education have endured as long as science has been present in the school curriculum. Some arguments focus on its competitive utility and contributions to economic development. Others focus on the social elements of science learning such as environmental awareness and health. And still others point to science applications in technology and engineering. Simultaneously, there are differences in views about who should learn science—the gifted elite or the common citizenry, propagating a long-standing tension in public education rooted in the earliest years of our public education system.

Now, with over fifty years passed since Sputnik and nearly ten years since the turn of the millennium, the need for science education in our country is greater than ever. Once again, we feel the pressure of competition, but this time it is not a race to space; it is an exercise of intellectual muscle. We find ourselves in a race with every country in the world to be leaders in the growing global, knowledge economy of the future. The priority of the past—creating more scientists—is even more timely today. Simultaneously, there is an undeniable urgency to have science fluent citizens. Science is no longer something distant. Students leaving our schools need to make decisions about advocacy for scientific research, the environment, and their own health. There is no longer any room for argument. Individually and as a nation, we need science to thrive, and survive.

Science Education Must Begin In the Earliest Years

A natural starting point for those eager to see the numbers of scientists grow is the high school. With the competitive drive to create more scientists, this is an obvious place to begin in order to see immediate progress. However, if we shift to a longer-term perspective, and recognize the two-pronged science education goal of developing science fluent citizens as well as scientists, we can see that devoting efforts primarily to high school is short sighted. If we are to meet all of our goals, high school is too late.

As notable leaders in education have said from early on, children need to learn science from their youngest years. Elementary (and preschool) science education provides the foundation of science experiences, processes, facts and concepts that are the essential building blocks for the knowledge necessary to live, engage and innovate in the 21st century. When all students have that foundation, those who would go on to be scientists will be even more prepared to pursue their goals of natural discovery. And those who do not will be well prepared to understand and support increasingly visible and readily relevant scientific work.

Unfortunately, even in light of the increasingly clear need for elementary science instruction, research tells us that the current emphasis on mathematics and reading in our nation's education accountability system is having negative consequences for science. A study by the Center on Education Policy (CEP) finds that, while 62% of US school districts increased the amount of time on Reading and Mathematics under NCLB, 44% of US school districts cut time on other subjects (Center on Education Policy, 2008). A report by Martin West of Brown University provides similar evidence using longitudinal data. He finds that from 1999-2004, time on Reading increased by about 40 minutes a week on average, but time spent on Science and Social Studies decreased 17 and 23 minutes per week, respectively (West, n.d.)

With the arrival of state testing systems for science, one could argue that science will now be a higher priority. However, the consequences for high quality science instruction are unclear. Given the variability of the tests themselves with regard to the nature of content and process knowledge they measure and the undefined consequences of poor performance, it is possible that what should be a positive support for high quality science education could become a detriment. While accounting for these circumstances, there is no question that we must develop elementary science education into the culture of American schooling. And, we necessarily need to identify the most effective strategies for doing so. While past efforts espousing the merits of elementary science education haven't been heard, now, as the global economy grows and science-related issues increase in the public eye, the time has come to embrace elementary science.

The Science Specialist Conceptual Framework: A Strategy for Developing Shared Language and Accumulating Knowledge

In light of the history of elementary science education, it is not surprising that there is a dearth of research on the best strategies for improving it (Gess-Newsome, 1999). There is, however, a wealth of documentation about the barriers that stand in its way. Teachers cite time, poor equipment, insufficient space, lack of content knowledge and interest, poor confidence, and lack of preparation as some of the reasons they are reluctant to teach science (Gess-Newsome, 1999; Raizen & Michelsohn, 1994; Tilger, 1990; Weiss, 1994). Taking these barriers into consideration, some have focused on an approach that could address these challenges and provide support to widespread improvement of elementary science instruction: the science specialist (Abell, 1990; Hounshell & Swartz, 1987).

In order to realize the potential of a science specialist intervention, however, we need to identify and understand the most appropriate and effective roles that a science specialist should play. Should a specialist teach in collaboration with elementary classroom teachers? Should a specialist teach in a room that is separate from the regular classroom? How should a specialist integrate science instruction into the rest of the school day? Should the primary audience of the specialist be teachers or students? There are many unanswered questions. Before we can answer them, however, we need to recognize that currently, the "science specialist" approach is ill-defined and as such, is a poor subject of study. Before we can engage in rigorous, systematic research to understand the elements of this approach that are most effective, we must find a way to clearly and specifically describe it, in all of its variations. Only with common language, can we develop as a learning community of advocates for elementary science education.

In 2002, the publication *Scientific Research in Education* stated, "… research in education has not produced the kind of cumulative knowledge garnered from other scientific endeavors." (Shavelson, R.J. & Towne, L., p. 28) This article proposes an approach for beginning the conversation of how we get there; at least with regard to the science specialist. It offers a framework for supporting shared language and conceptual understanding, along with a process for identifying and organizing the elements that comprise science specialist models. With these first building blocks, it is our hope to create a foundation for accumulating knowledge about how to bring high quality science education to elementary schools.

The strategy described here builds on current work from the Center for Elementary Mathematics and Science Education (CEMSE) at the University of Chicago. CEMSE received funding from the National Science Foundation (NSF) to work with the Chicago Public Schools over three years to develop a suite of instruments for measuring the use of standards-based science and mathematics instructional materials at the K-8 level. When complete in 2009, this project will have produced a suite of instruments for measuring use of five science curricula – *FOSS, STC, Science Companion, SEPUP,* and *IES* – (as well as *Everyday Mathematics*) and a *User's Guide* that describes procedures for adapting the instruments for use with other instructional materials and instruction not associated with a particular program. For more information on these instruments, go to <http://cemse.uchicago.edu/foi>.

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At the outset of this work, we recognized that in order to develop data collection tools for use across a "family" of interventions (e.g. a group of interventions with many shared characteristics but still quite varied - in this case, reform-based science instructional materials programs) we needed a conceptual framework that would encompass the range of elements common to the interventions but still allow us to identify and clearly and specifically describe their differences. We accomplished this by developing a conceptual framework (described further below) that became the basis of our instrument development. Along the way, we came to realize that we could apply the framework, and the process we engaged in to develop it, to other interventions. This article reflects our effort to apply that work to the intervention of interest here—

the science specialist—in order to initiate a dialogue that will lead to a rigorous, collaborative community of researchers studying the potential of this model in all of its variations.

The process we followed was emergent and iterative, but in retrospect, for these purposes, we can retrospectively identify the following steps: 1) describe the intervention and its "critical components"; 2) organize the components into categories within the framework; 3) develop clear and specific definitions for the critical components; 4) identify models or "types" of science specialists; 5) identify and/or develop tools to measure the critical components based on the clear and specific definitions.

Only with common language, can we develop as a learning community of advocates for elementary science education.

So, although we may be impatient to learn more about the potential of the science specialist intervention, we need to ensure that as we move forward, we have the tools we need. In the pages that follow, we make a first attempt by applying these steps that have worked for instructional materials interventions to the science specialist intervention model. In doing so, we begin to "map" the components that comprise the science specialist models into a framework that can be a tool for supporting the shared vocabulary, common measures, and organizational structure that will help us more accurately interpret our findings and together accumulate a sound growing body of knowledge.

1) Describe the Intervention and Its Critical Components: The first step for developing a tool for accumulating knowledge on an intervention is a clear description of all of the essential elements that comprise that intervention strategy. Indeed, the "science specialist" intervention strategy suffers from a problem pervasive in education: the absence of a clear and specific definition. "Science specialist" has been a catch-all label in science educators' conversations (used synonymously with phrases like "science resource teacher," "science coach," and "science lead teacher") nearly assuring that we are not communicating the messages we think we are to one another.

Rather than focus on the labels and debating the meaning of each, we can instead direct our attention to identifying and defining the range of elements any model could have. This focus on what we in CEMSE have come to refer to as the "critical components" of the intervention builds on earlier studies that highlight their use as key to measuring implementation. Hall & Hord (1987) for example, note that in order to analyze different instantiations of a program, "the components or building blocks of the innovation must be identified" (p.117). They later refer to these as "innovation components" and "critical components" (1987). Wang refers to the essential elements of instructional materials as "critical program dimensions" (1984) while others stress the importance of identifying and operationally defining "model dimensions" (Bond et al., 2000).

In other words, "critical components" are the elements of an intervention that are essential to its implementation. They are the variables one must measure in order to determine the extent to which the intended intervention is in place, and in turn, the impact of that intervention. Likewise, they are the variables one must identify and measure in order to engage in studies that clearly and specifically compare interventions and their relative effectiveness. Clearly articulating critical components of the science specialist intervention is key if we are to make progress in understanding the impact of science specialists as an improvement strategy.

Leithwood and Montgomery (1980) suggest that information about the critical components of programs should be taken from the program developers, written materials produced by the developers, or those involved in the implementation of the program. While not exactly a "program" we can apply this approach to the science specialist intervention. A meeting convened by Education Development Center in September 2007 generated a strong starting point. The meeting brought together district and school leaders engaged in using science specialists, individuals serving in the science specialist roles, and researchers and evaluators who had written about science specialist models. (The outgrowth of this meeting is chronicled in the first article of this issue of the *Science Educator*.) These three audiences have the knowledge and experience to articulate the elements of the science specialist intervention model. It is worth nothing that it is often the case that "models" of interventions are not necessarily explicit at the outset. But descriptions of science specialist interventions, their comprising elements, and the theories of action regarding their impact—even when implicit—are models, nonetheless.

When asked to identify the elements of their "science specialist" intervention, the meeting participants generated lists of roles and responsibilities that comprised the operational definitions of their science specialist models. The list read like a proverbial collection of "apples and oranges" ranging from "materials set up, refurbishment and management" to "take responsibility to continue to learn." A selection of the complete list, as generated by participants, is in table 1.

Table 1. Science Specialist Roles Identified by EDC Meeting Participants

Role		Role	
1	Teach students science in science room	7	Conduct Professional Development – lesson study
2	Teach students science in another room	8	PD – demonstration lessons
3	Set up, refurbish and manage materials	9	PD – kit trainings
4	Take responsibility to continue to learn	10	PD – principal trainings
5	Plan with classroom teacher	11	PD – special education trainings
6	Collaborate with other specialists	12	Assist with test preparation

These roles reflect the wide ranging ways science specialists can contribute to improving science education. There are many more, including providing assistance to teachers while they teach, providing materials to teachers, coaching teachers, facilitating data based decision making, science curriculum assessment and revision, conducting system-wide science festivals, designing laboratories and co-teaching; and the list can go on. (Rhoton, Field, and Prather, 1992; Gess-Newsome, 1999). Given the variation, it appears that there are countless models comprising different combinations of roles.

The first step for developing a tool for accumulating knowledge on an intervention is a clear description of all of the essential elements that comprise that intervention strategy.

Thus, although these roles were described within the contexts of models currently in place, the names of the models are not important. As we learned in our work measuring instructional materials, when we start using names for interventions that aren't clearly and specifically defined, we cannot be certain that others understand our assertions and findings. Thus, the key is to throw away our labels and instead describe our models using the combinations of "critical components" that comprise them. With these descriptions, we have a tool for knowing where models are similar and different and a basis for research that can explore the elements of those models (alone or together) that seem to contribute most to our desired outcomes.

The process of identifying critical components calls for more than articulating a list of intended roles like those above. These are often the most explicit elements, but there are also other inferred critical components that are either so obvious, or are so subtle, that sometimes even program leaders haven't clearly identified them. For example, there are expectations not only for what science specialists need to do, but also for what they must know in order to fulfill the expectations of the science specialist position. There are also expectations for the nature of specialists' interactions with their "recipients" (whether it be teachers or students); and, for the recipients' interactions with the specialist. As the list of components grows, one can see the value of organizing them into different categories.

2) Organize the Elements into Categories within the Framework: As we proceed with organizing the critical components of science specialist interventions, we will turn to the conceptual framework CEMSE developed for guidance. Notwithstanding the differences in instructional materials and science specialist interventions, the basic framework structure still applies. Using it as a starting point, we will develop a science specialist conceptual framework that will support the clear description of science specialist models, and facilitate the accumulation of data and knowledge on the different critical components.

Following, is a brief description of the existing instructional materials implementation conceptual framework. As we developed this framework, we carefully considered others' approaches to measuring implementation and in the end chose an approach aligned with Mowbray, et al. (2003) who focused, as already mentioned, on the "critical components" of the programs.

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Mowbray, et al., (2003) organizes what they call "fidelity criteria" (our critical components) into two groups - those that focus on structure ("framework for service delivery") and others that focus on process ("the ways in which services are delivered"). Mowbray, et al. weren't the first to organize program elements this way. In 1984, Wang, et al. studied the Adaptive Learning Environments Model that identified two types of "critical program dimensions." In their work, the structural program elements were described as "those that relate to the provision of adaptive instruction" and the process elements included those that relate to "supporting effective implementation of adaptive instruction. The CEMSE conceptual framework builds on these and others (Dane & Schneider, 1998; Dusenbury, Brannigan, Falco, & Lake, 2004; Lynch & O'Donnell, 2005; Lynch S., 2007; Mowbray, et al., 2003) who measure implementation of interventions in two general categories that we came to informally refer to as "structure" (our structural critical components) and "process" (aligned with our instructional critical components).

The framework (Figure 1) has two broad categories of critical components of instructional materials interventions: 1) Structural Critical Components and 2) Instructional Critical Components. Structural critical components reflect the design and organization of the physical materials. Instructional critical components, on the other hand, reflect the intended behaviors during classroom interaction. Then, each main category has sub-categories that further classify the critical components.

In the "Structural" category, procedural critical components are the organizing structural elements of the program (e.g. order of activities within the lesson, time spent on instruction, lesson overview). In other words, they focus on expectations for what the teacher needs to do. The educative critical components, on the other hand, are structural representations of the developers' expectations about what the teacher needs to know in order to teach the program (e.g. unit level information on content, background information on pedagogy). These components represent a recognition that teachers need a certain minimum level of content and pedagogical knowledge to teach reform-based programs and that while some teachers come to the classroom with this knowledge, others do not. Given the fact that developers cannot rely on all teachers receiving the same amount of professional development, educative program components are analogous to "built-in" professional development.

In the "Instructional" category, pedagogical critical components reflect the developers' expectations about the teacher's behaviors during instruction (e.g. teacher facilitation of group work, teacher facilitation of reasoning). In other words, they represent the instructional strategies the teacher needs to employ and interactions the teacher needs to have with students in order to use the program as intended. Similarly, there are student engagement critical components (e.g. students engage in discussion, students communicate) that reflect the developers' expectations for what the students need to do in order for the program to be enacted as intended. Together, the instructional critical components represent the developers' beliefs about the nature of the instruction that will lead to desired student outcomes.

Given that this framework built from others' work across multiple fields studying different types of interventions, its applicability to a range of programs in education is not surprising. To operationalize this idea for the science specialist then, we begin with the intervention critical components identified in the last step. Figure 2 demonstrates one way to organize the science specialist critical

Figure 1. Instructional Materials Intervention Conceptual Framework

Implementation of Instructional Materials Interventions			
Categories of Critical Components			
Structural Critical Components		Instructional Critical Components	
Procedural	Educative	Pedagogical	Student Engagement

components into categories within the framework for easier communication and analysis.

Structural Critical Components

Like the framework for instructional materials, the science specialist framework includes structural procedural critical components. These critical components are the organizing elements of the program and communicate intentions about what the science specialist should do. For example, critical components in this category could address structures such as "the specialist's "home base" (classroom, school laboratory, district office) and the amount of time that is committed to his role as a specialist (e.g. full-time classroom teacher; half-time; full-time released). They also can communicate the roles the science specialist is intended to play (e.g. organize and distribute materials; plan with teachers, communicate with parents).

The educative critical components of instructional materials programs focus on the content, pedagogy and assessment background the teacher needs in order to teach the program. In the case of the science specialist intervention, the educative critical components reflect what the specialist needs to know in order to enact the specialist model as intended. In addition to science content, pedagogical strategies, strategies to support adult learners, and knowledge of the curriculum, Gess-Newsome (1999) suggests that they need knowledge of students and how to plan for and assess student engagement.

In instructional materials interventions educative critical components are evidenced in the programs' written materials (e.g. sections on science content background information and background information on supporting small groups). In the science specialist model, educative critical components may evident in written materials provided for the specialist, but they are more likely to be evident in professional development experiences provided for the specialists. These may range from individual topic-based workshops to on-going, in-depth study groups.

Figure 2. Science Specialist Intervention Conceptual Framework

Implementation of Science Specialist Interventions			
Categories of Critical Components			
Structural Critical Components		Instructional Critical Components	
Procedural	Educative	Student Educator	Student Engagement
		Adult Educator	Adult Engagement

Clearly articulating critical components of the science specialist intervention is key if we are to make progress in understanding the impact of science specialists as an improvement strategy.

Instructional Critical Components

On the right side of the framework, rather than two sections beneath the heading, there are four - two for each of the main audiences specialists may serve—students and adults. Like the instructional critical components in the materials interventions, these critical components can occur at any time in the specialist-recipient interaction and as such are not bound to particular roles identified on the structural side. When the science specialist is acting as a student educator, the instructional critical components are quite close to, if not the same as instructional strategies/ pedagogies a teacher would use and thus, map quite closely to those already identified as part of the instructional materials conceptual framework. This is the case for student engagement as well. For more on the instruments already developed for measuring these critical components, see the section on measurement below.

For the models that entail the specialist acting as a teacher to adults, other critical components would apply. For example, "specialist supports the development of teacher confidence" may be an instructional critical component. Within the constraints of any particular science specialist model, behaviors indicating the presence of instructional critical components can occur at any time and so are measured independent of the structurally identified roles.

The student engagement critical components reflect expectations about the students' participation in the instructional process including their interactions with the content as well as with the teacher and one another. Like the pedagogical critical components, these critical components (with a few exceptions) are not tied to specific section(s) of the lesson or teacher's guide. In the case of the adult learners, the critical components reflect the expectations for the adults' behavior during the specialist-adult interaction. For example, "teacher seeks advice of specialist" is an example of an adult engagement critical components.

As we revisit the roles identified at the EDC meeting in light of the framework categories, we can see that nearly all of them are structural-procedural critical components. This is not unexpected since in this particular context the meeting participants were asked to identify some of the structural roles specialists play. However, if one is to measure the implementation of the science specialist intervention, it is essential to measure the other elements of the intervention as well.

Of course, any intervention to improve instruction is necessarily complex; critical components most certainly cross boundaries. While the organizational structure described here could change with a continued dialogue in the field, it is a first attempt to demonstrate how we can build from work already in place to benefit new questions about improving education. It paints a picture of a place where we have clarity of our terms and can have a common framework to guide the sharing of data and findings with reasonable compatibility.

3) Develop clear and specific definitions of the critical components: Once we have identified the critical components, we need to define them, clearly and specifically. To simply say "co-plan with teachers," for example, leaves many unanswered questions such as: what is the nature of the planning, the length of the planning, and the focus of the planning? Likewise, "manage and organize materials" while somewhat more focused, needs a clearly articulated description. Without it, one would have no way of knowing whether the specialist is responsible for organizing an old materials closet, or for providing each classroom teacher with neatly packaged materials for each lesson. Developing definitions for the critical components that reside in the framework is beyond the scope of this paper; and ideally, this is a process that is not done in isolation. Definitions, with concrete observable, measurable behaviors must emerge from the field, and then adjust over time with more refined, agreed upon meanings.

4) Identify models or "types" of science specialist models: In a report by Jones and Edmunds (2006) they identify three models for science instruction – "traditional" (the classroom teacher teaches science), "specialist" (the teacher serves the whole school from a lab); and "science resource teacher" (supplements classroom teaching with whole class instruction and workings with teachers). They refer to these models as "archetypal variation" and indeed, they, and others like them are embedded in the dialogue about science specialists that take place across the field.

While the organizational structure described here could change with a continuing dialogue in the field, it is a first attempt to demonstrate how we can build from work already in place to benefit new questions about improving education.

But rather than introduce confusion into systematic efforts to learn about the models by using poorly defined names, we can use the framework and its comprising critical components to specifically describe the models of interest. It is better to bypass the vague model names and focus instead on the specifics that comprise the models.

Table 2 shows a hypothetical list of critical components and model titles. The first row identifies some of the ways we currently refer to different science specialists. The phrase "resource teacher" or "science specialist" are no more informative than "regular classroom teacher" and as such do not help us further knowledge in the field. The next row indicates how one can use names as "generic" titles and then define the generic model name by indicating the critical components present in the model.

For example, rather than conduct research on an intervention known as the "in-school specialist" model and accepting its vague—or even absent—description, we can instead suggest that science specialist model "A" comprises critical components "1," "3," "4," "7," and "9." Using this approach, another researcher or community using an in-school science specialist model, will do the same for their model "B" and together, we will be able to discern the extent to which the models are in fact the same. This strategy is similar to Hall and George's (2000) work using what they referred to as "innovation configurations" to assess program implementation. They refer to their innovation configuration map as a "roadmap" documenting the presence of program components in implementation (Hall and George, 2000).

As mentioned at the beginning of this article, these steps are, in fact, not discrete steps at all. For example, identification of the critical components comprising a model can take place at the beginning of the process when determining what the intended science specialist model is; and, it can take place during or after implementation, when one seeks to determine what the enacted science specialist model is, or was. This flexibility represents the fact that when models are implemented in increasing numbers of settings, variation is inevitable. And not only is it inevitable, one could argue that it is desirable; we expect that specialists will vary what they do based on the contexts and conditions surrounding their circumstances. Thus, the framework serves as a tool for describing the variations that the specialists make to their intervention model and in turn, interpreting the extent to which the contexts and conditions surrounding the implementation of the model affect it and its relationship to desired outcomes.

In other words, we do not need to agree on what to call the models. Rather, we need to agree on describing the models using critical components and their accompanying definitions that reside in a shared conceptual framework. By documenting the components of the intervention at this level of specificity, we can begin to accumulate data and knowledge not only on the larger models, but on the individual components that comprise them. In the end, we can move closer to our goal, which is not to determine which "model" is best; but rather it is to determine the combinations of components that work under particular circumstances to achieve our particular desired outcomes.

Definitions, with concrete observable, measurable behaviors must emerge from the field, and then adjust over time with more refined, agreed upon meanings.

5) Identify and/or Develop Measures of the Critical Components Based on the Clear and Specific Definitions. The science specialist intervention framework is a helpful tool for talking with one another. And, it can be used as a landscape on which we can place rich and specific descriptions of our interventions and where they do and don't overlap with other models or with "business as usual" approaches to science instruction. While supporting the field's discussion of science specialist models through the use of common language and clarification of components of each model, further utility of the model comes with its support of accumulation of data and findings on the different components of science specialist models and their relationships with desired outcomes.

Clear and specific measures of classroom practice are critical tools for understanding which interventions, and practices associated with those interventions yield desired student outcomes. In this case, there are some existing instruments that one can use to measure the presence of a portion of the identified critical components. On the instructional side of the framework, when the specialist is in the "student educator" portion of the framework, he is in fact acting as a teacher and existing measures of teacher and student interactions during instruction apply.

A sound starting point are the instruments developed through CEMSE's currently funded NSF project mentioned earlier. In 2009, CEMSE will release a suite of instruments for measuring implementation of five science instructional materials programs for grades K-8 and *a User's Guide* that describes procedures for adapting the instruments customized for these particular programs for use with other instructional materials and "business as usual" classrooms. Among the seven instruments in the suite are classroom and school observation protocols, teacher and school leader questionnaires, teacher and school leader interview protocols, and a teacher instructional log. These instruments focus on measuring the use of reform-based instructional materials, but can be applied to measures of teacher and student interactions and behaviors during instruction and thus, can support data collection on science specialists who interact directly with students.

It is important to acknowledge that there are at least two well-known existing observation protocols for collecting data on science instruction. They are *Inside the Classroom Observation and Analytic Protocol* (ITC COP) (Horizon Research, Inc., 2003) and the Reform Teaching Observation Protocol (RTOP) (Sawada, et al., 2000). One of the key distinctions between the CEMSE instruments and these is that the Horizon and RTOP instruments target data collection on reform-based science instruction broadly defined while CEMSE's constructs address instruction, but do so within a broader conceptual framework that supports detailed analyses of relationships

Table 2. Hypothetical list of Critical Components and Distribution Across Models

Too general to Accumulate Knowledge	Traditional or regular classroom teacher		Science Specialist Alone			Specialist-Teacher Combo with Classroom			Resource Teacher Combo with Classroom	
Generic Model names	Traditional Model A	Traditional Model B	Specialist A	Specialist B	Specialist C	Specialist Teacher A	Specialist Teacher B	Specialist Teacher C	Resource Teacher A	Resource Teacher B
Possible Critical Components from the Conceptual Framework										
1. Organize materials	•	•	•	•	•	•	•	•		•
2. Manage materials	•	•	•	•	•	•		•		•
3. Provide materials						•			•	•
4. Outreach to parents	•	•	•				•	•	•	
5. Outreach to community		•	•				•	•	•	
6. Supervise teachers								•		•
7. Collaborate: coaching and mentoring							•			•
8. Collaborate: planning							•			•
9. Collaborate: co-teaching		•					•			•
10. Model instruction in science room		•	•				•			
11. Model instruction in teacher's room						•		•		•
12. Be a leader			•			•	•			•
13. Assist during a lesson						•		•		
14. Lead professional development										•
15. Facilitate school-wide science related events			•	•			•		•	

between those constructs and materials interventions. Furthermore, the RTOP observation protocol is a stand-alone instrument while our instruments (and the Horizon instruments) are part of a larger suite of data collection tools supporting more flexibility of use and triangulation of findings. Also under development at EDC is the Inquiry Science Instruction Observational Protocol (ISIOP), which is focused on determining the nature and extent of science instruction in middle grades.

Together, these instruments may comprise a complementary collection of tools to measure the critical components that reside in the cells of the framework focusing on teacher and student behaviors and interactions during instruction.

However, the instruments that measure the other critical components on both the structural and instructional sides are lacking. Here we have yet another reason to work from a shared conceptual framework with shared language. The CEMSE instruments provide an example of what measures of structural critical components can look like, but they are only an example since the structural critical components of science specialist models are of a completely different nature. As we move forward, it is essential to ensure, as much as possible, that instruments focused on these areas are, in fact measuring components defined in similar ways and ideally, are compatible so that we can truly accumulate data and findings to develop a growing body of knowledge in our field.

Where does this Framework reside in the larger research agenda?

Now that we have developed a conceptual framework for the science specialist intervention, it is important to acknowledge that carefully and specifically describing any innovation is just one small piece of the larger research landscape. Looking at figure 3, one sees a very simple illustration of where the science specialist conceptual framework resides. In this over-simplified scenario, a science specialist intervention is implemented with the expectation that it will lead to desired student outcomes. However, interventions are rarely, if ever implemented as intended. Implementation is shaped by various contexts and conditions that reside outside of the intervention (e. g. administrator support, the presence of instructional materials, student demographics). Thus, in order to draw truly meaningful conclusions about the impact of the science specialist model, it is essential to do more than determine the nature of its implementation; we also need to account for the other variables affecting the implementation and outcomes.

The science specialist intervention framework is a helpful tool for talking with one another.

We know that there are many elements of improving science instruction that could be considered "inputs" to an enacted intervention. In the case of the science specialist, we might consider financial resources, materials, and time. Likewise, there are many contexts and conditions that affect the implementation of the intervention, sometimes at more than one point during the intervention's duration. These might include characteristics of teachers (e.g. years of experience, confidence in their instruction), student demographics, and accountability systems. And of course, researchers would want to measure outcomes – ranging from student outcomes (e.g. science content and process as well as attitude) to teacher outcomes (e.g. teacher engagement, development of teaching strategies, pedagogical content knowledge) and system outcomes (e.g. visibility of science, increased commitment of time to science, and community involvement).

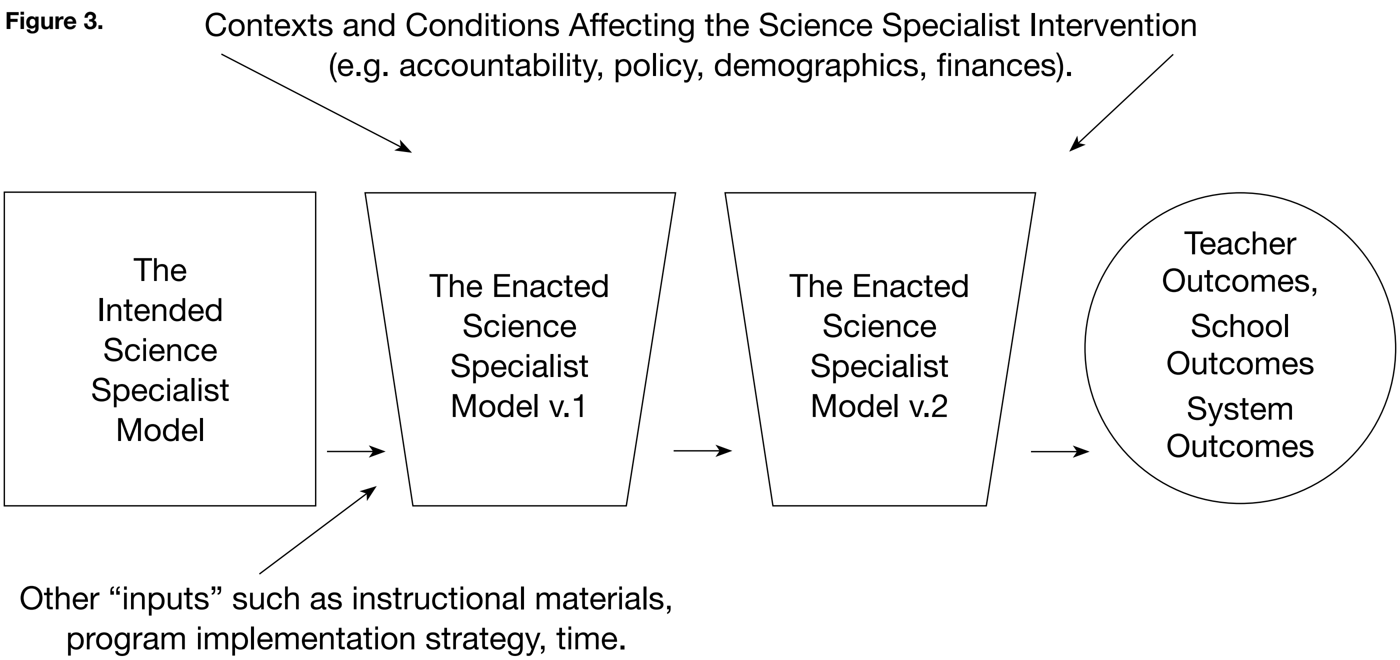
It is unlikely that any single research effort will focus on all of the reform elements illustrated in this diagram. Thus, it is essential to be able to "map" the findings of our studies on this larger landscape with language and tools that are compatible. The science specialist conceptual framework described here is only part of the picture. Researchers can use it to describe the intended science specialist model, and then to measure and describe the model as it is enacted over time, with the expected shifts from the intended model.

With the models named and specifically described, we can explore many different hypotheses about the possible impact of science specialist models and the "pros" and "cons" of each. For example, when there is no specialist, one might make the case that the teacher can fully integrate science teaching into the regular instructional day and other subjects; students can have science present as part of their regular classroom setting; and the teacher can differentiate instruction based on his knowledge of the students' strengths and weaknesses. However, the model creates a scenario in which the teacher is not likely to have a degree in a science content area, and has a greater ability to make science a lower priority in the instructional day.

In contrast, one could consider the pros and cons of a specialist model in which the children have a separate science class. Some of the benefits of the model include: regularly scheduled science instruction; a science teacher more likely to be knowledgeable and/or experienced with science teaching; and the experience of working in a science "lab." Shortcomings include: less integration of science with other classroom instruction, the apparent lack of engagement their regular classroom teacher has with science, and the implication that science is separate from other areas of study.

We could imagine both of these approaches embedded in a study in a large school district that assigned its schools to two different types

Figure 3.



of models. In one case, there are science specialists, and in the other, the teachers are responsible for the regular classroom instruction. At the end of the school year, researchers might find that students in the science specialist schools perform better. Or, they may find the opposite. Or, they may find no difference at all.

In order to draw meaningful conclusions from this study, we must ask ourselves – what happened in the science specialist schools? What roles did the science specialists play? Were some enactments of the science specialist role different from others? Were there people in the comparison schools who were enacting some of the same roles, even though they weren't "official" science specialists? Data collected with tools grounded in the framework will not only help answer these questions and increase the rigor and clarity of the study, they also have the potential to contribute to broader understandings about these models in the field.

Next Steps

This framework is a first attempt to organize the wide range of strategies underlying the science specialist models into a meaningful structure that will help us build a knowledge base about these models in our field. We would expect others would refine, revise, or perhaps completely re-invent the framework; it is the nature of systematic research. It must build on work that came before and contribute to work that is yet to come.

This framework is a first attempt to organize the wide range of strategies underlying the science specialist models into a meaningful structure that will help us build a knowledge base about these models in our field.

In *Issues in Education Research: Problems and Possibilities*, Cohen and Barns (1999) state, "The lack of systematic intervention that is linked to careful research also has contributed to the scattered and frequently inconclusive character of research and the inability to decide what had been solidly learned from a very important tradition of deliberate inquiry"(p.38). Thus, the main purpose of this framework is to support a continued conversation among educators, policy makers and researchers that benefits from shared, clear language and will move us toward a less "scattered" body of knowledge. We will not be able to navigate the landscape of research questions regarding science specialists and accumulate knowledge we can share if we aren't using the same map. This is not a simple task. It is not easy to arrive at the level of clarity and specificity we need - particularly if we need to come to agreement with others. The time has come for us to embrace the complexity of solving educational problems through research by collaborating as a community and making the essential, albeit sometimes difficult, commitment to speaking the same language and sharing tools. We need all of the benefits of our collective knowledge; the challenges of improving elementary science education are far too difficult to take them on alone.

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Jeanne Century is the director of science education, Center for Elementary Mathematics and Science Education, CEMSE Physical Sciences Division, University of Chicago, 5640 S. Ellis Ave. EFI Box 15, Chicago, IL 60637. Mollie Rudnick and Cassie Freeman are researchers at CEMSE. Correspondence concerning this article can be sent to <jcentury@uchicago.edu>.