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Introduction to *A Leader's Guide*

This book, *A Leader's Guide to Science Curriculum Topic Study*, is the natural companion to the parent book, *Science Curriculum Topic Study: Bridging the Gap Between Standards and Practice* (Keeley, 2005). The CTS parent book provides an introduction to the process of curriculum topic study (CTS); the resources used to engage in CTS; various ways to use CTS to support content knowledge, curriculum, instruction, and assessment; and the 147 CTS guides that contain the prevetted readings used in CTS. It has become an essential resource used by science educators to improve their practice. This *Leader's Guide* offers practical suggestions for using the CTS parent book, including tools, designs, and additional resources for incorporating CTS into the work science leaders do to support teacher learning. The *Leader's Guide* was developed to assist teacher educators and leaders, such as preservice faculty, scientists who provide content support to teachers, science specialists, teacher leaders, and professional development providers, in developing the professional knowledge base science teachers need to be effective in the classroom. It provides tested strategies for introducing the CTS process that builds preservice and inservice teachers' knowledge of the research on learning science and the national standards and benchmarks that are the bedrock for ensuring quality teaching and science literacy for all. Furthermore, it supports forms of teacher learning in collegial groups and professional learning communities (PLCs) that are guided by a common knowledge base as teachers work together to plan lessons, examine student work, develop assessments, select curriculum, and go about the daily business of educating our nation's youth.

ADVICE FOR USING THIS *LEADER'S GUIDE*

Users of this *Leader's Guide* may wonder how they should begin using this book. You may be asking, *Where do I start? In what order do I use it*? *What else do I need to effectively use this book?* There is no single answer to these questions. It depends on your familiarity with CTS and your purpose for using it. We do encourage all leaders who use this *Leader's Guide* to have a copy of the CTS parent book, as well as the resources listed in Table 1.1. Often, throughout this *Leader's Guide*, we will be referring you to sections and pages in the CTS parent book, and it will help you to have it to consult.

Before you begin using this *Leader's Guide*, it is important to become familiar with the CTS parent book, CTS resources, and experience a CTS. If you have never conducted a CTS on your own, pull out your CTS parent book. From it, select one of the 147 CTS topics of interest to you and follow the process described in Chapter 3 of that book, "Engaging in Curriculum Topic Study." Wear two hats as you conduct your own CTS: (1) As a learner, reflect on what knowledge you gained as you did the CTS, and (2) as a professional developer, consider what you need to do to facilitate this type of learning with others. Compare what learners do with what a facilitator would do throughout the process on pages 48–49 of the CTS parent book to get a sense of what the teachers with whom you work will be doing and what you will be doing as a CTS facilitator.

Table 1.1 Essential Resources for Leaders of CTS

CTS Resources	*Available Through*
Science Curriculum Topic Study (Keeley, 2005)	Corwin: http://www.corwinpress.com NSTA Press: http://www.nsta.org/store/
Science Matters (Hazen & Trefil, 1991, 2009)	Major bookstores and online sellers
Science for All Americans (AAAS, 1989)	Oxford University Press: http://www.us.oup.com/us/ NSTA Press: http://www.nsta.org/store/ Available to read online at: http://www.project2061.org/publications/sfaa/default.htm
Benchmarks for Science Literacy (AAAS, 1993)	Oxford University Press: http://www.us.oup.com/us/ NSTA Press: http://www.nsta.org/store/ Available to read online at: http://www.project2061.org/publications/bsl/default.htm
National Science Education Standards (NRC, 1996)	National Academy Press: www.nap.edu NSTA Press: http://www.nsta.org/store/ Available to read online at: http://www.nap.edu/catalog.php?record_id=4962
Making Sense of Secondary Science (Driver et al., 1994)	NSTA Press: http://www.nsta.org/store/ Online booksellers
Atlas of Science Literacy (Vols. 1–2) (AAAS, 2001, 2007)	Project 2061: http://www.project2061.org/publications/atlas/default.htm NSTA Press: http://www.nsta.org/store/

CTS is a versatile professional development tool with multiple uses and purposes. We do not prescribe a linear, step-by-step process for using CTS in your work. Where you start, the sequence you use, the designs you select, the tools you use, and the supplementary resources you include will be as varied as the diverse types of leaders who are using CTS. Each of the chapters in this book will begin by describing what is in the chapter and how leaders might use it. While step-by-step scripts are provided for many of the CTS designs, we encourage you to adapt the materials to the needs of your audience and to your own facilitation style.

Before implementing the designs, tools, and suggestions in this book, it is important to have a deep understanding of how CTS enhances professional development, the different purposes it achieves for teacher learning, the variety of ways to embed it into your own teacher learning contexts, and the language used throughout CTS and this book. This groundwork should be done first if you plan to regularly use CTS in your work. This chapter addresses the question, "Why use CTS?" It will provide you with the rationale for using CTS and lay the groundwork for you to use the material provided in the subsequent chapters.

UNDERLYING BELIEFS

As suggested in the preface to this book, the education field has undergone a tremendous transformation in beliefs about what constitutes effective learning for both children and adults and what it takes to be a quality teacher. There is a growing recognition of the complexity of teaching and the vast array of knowledge a teacher must possess to meet the needs of a wide range of students. We know more now than ever before about conceptual learning in science and the skills necessary to do science, and we are learning more all the time. As the education field, and in fact our entire culture, becomes one that is knowledge-using and knowledge-producing, teachers are increasingly using and contributing to the education knowledge base. These developments have provoked the following two strong beliefs that undergird the CTS work:

1. Teachers, like other professionals, must possess and continue to build their own *specialized knowledge base*. For teachers, this consists of content knowledge and knowledge about teaching in a specific content area, including an understanding of how children of a certain age learn, called pedagogical content knowledge (PCK). Teachers continue throughout their careers to develop and actively use their specialized knowledge base to guide their educational practice.
2. Teachers, like other professionals, should be engaged in *collegial learning communities* that are guided by strategic and enduring goals and focused on enhanced learning and ongoing improvement. These communities should be knowledge-using and knowledge-producing and be guided by two very basic ideas: Use the knowledge generated from standards and research to provide evidence and justification for your ideas, and learn from the expertise of others shared through peer-reviewed literature, conference presentations, and the wisdom of thoughtful practitioners.

Each of these beliefs has changed how we think about the content and purpose for professional development for science teachers and has had a major impact on how teachers are engaged in professional learning. CTS supports teachers to build their specialized teaching knowledge and participate in productive collegial communities focused squarely on putting research and standards to work in the classroom. Throughout this book, you will see examples of how teachers can use CTS to enhance their content and pedagogical knowledge in collegial, collaborative learning environments. You will see how teachers use knowledge gained from CTS as well as contribute new knowledge about teaching and learning in their own unique contexts through professional development strategies described in Chapter 7, such as action research, lesson study, and video demonstration lessons.

THE NEED FOR A COMMON PROFESSIONAL KNOWLEDGE BASE

Over the last few decades the education field has learned more about what it takes to develop qualified teachers in science and the knowledge, skills, and mind-sets that support teaching and learning in this discipline. New ideas have been shaped and influenced by the growing research base that provides educators with insights into how students develop their understanding of specific ideas in science and how preconceptions may impede learning if they are not surfaced and taken into account when designing instruction. There is greater awareness and use of recommended practices such as establishing a clear and coherent curriculum, focusing on an explicit set of standards-based learning goals, using instructional strategies that support and deepen student learning of key ideas in science, and embedding standards- and research-based assessments throughout instruction that inform teaching and provide information on the extent to which students are achieving a learning goal. Increasingly educators are asked by administrators and others to justify requests for new programs or practices with objective evidence of success. Stakeholders want to know what works and are looking to professional educators to identify and explain effective practices that can lead to increased student achievement.

These developments have given way to new ideas about teacher professional development. We know that science teaching involves much more than hands-on activities, teaching tips, and general pedagogical techniques. Professional teachers must possess both content and PCK, the specialized knowledge of content and how children learn it. This knowledge enables teachers to focus on important learning goals and provide developmentally appropriate instruction and assessments. Quality professional development programs are increasingly focused on enhancing teachers' understanding of their content and how to teach it. Teachers are learning to review and revise their instructional materials and methods to better reflect alignment with standards and research on learning and are taking collective responsibility for knowing not only their content, but also how children think about ideas in science and what types of experiences, phenomena, and representations can best support learning.

One of the characteristics of professional teachers is their belief in the importance of acquiring their own professional libraries or having access to professional resources to regularly inform their teaching and expand their knowledge base. Knowledge of effective science teaching does not end after graduation from a teacher preparation program or graduate program. Teachers are constantly seeking the wisdom and knowledge shared by researchers and expert practitioners that help them grow and develop as professional science teachers. There is a plethora of professional literature to support science teacher learning. However, the vast collection of literature can be narrowed down into six major publications that best support standards- and research-based teaching and learning across all the science disciplines, grade levels, and teacher expertise. These are the common and collective resources identified by the CTS Project that can be used with the 147 science curriculum topics identified in the CTS parent book. These professional resources should be in the library of every science teacher and teacher educator, whether they are part of their own collection or shared within a school or organization. These resources are listed in Table 1.1 and provide a common knowledge base that all teachers can refer to and use. The fact that these books were authored by highly respected scientists, researchers, and science educators and some, such as the national standards documents, went through an extensive national review process that involved consensus from the science education community at large, makes them credible and relevant to all science educators striving to develop shared understandings of content, teaching, and learning. Having access to these books is like having an expert at your fingertips 24/7!

CTS MAKES THE KNOWLEDGE BASE ACCESSIBLE

As described in the preface, many teachers, and even some teacher educators, have never used or even heard of some of these resources, even though they have been out for more than a decade. As the use of CTS grows, these resources are becoming better known and more frequently used in the science education community. As a facilitator, one of the changes you will see firsthand as you use CTS with teachers is the renewed emphasis and embrace of the national standards and research literature, even though states have their own standards.

Prior to CTS, getting to know and use national standards and research on learning posed several difficulties. The focus on state standards shifted teachers' attention away from the more detailed source documents on which many of these state standards were based. As we discussed in the preface, we found that many teachers had no knowledge of publications like *Science for All Americans* and *Making Sense of Secondary Science.* Some had heard of the *National Science Education Standards* and the *Benchmarks for Science Literacy* but had never opened a copy or even realized that these publications contained much more than a list of what students were expected to know and be able to do in science. They didn't know enough about the publications to know how useful they could be in informing teaching and learning.

For others, the standards and research publications were available but a process for using them was missing. Some teachers found navigating through the publications to be difficult and unwieldy. They consulted the standards documents, sifting through the hundreds of pages of text to find what was relevant to their curriculum, their students, or their teaching and often struggled and became frustrated because the answers they were seeking were so hard to find. They didn't know how to use the essays or why the learning goals were written a certain way. They struggled with figuring out how to sequence and connect standards coherently. Many never realized there was a chapter in the back of the *Benchmarks* that contained summaries of research connected to the chapters describing what all students should know. They didn't realize how *Science for All Americans* is the seminal, enduring document that lays out the vision for the standards documents. And few knew of an obscure little book published in England, *Making Sense of Secondary Science: Research Into Children's Ideas* (Driver, Squires, Rushworth, & Wood-Robinson, 1994), that contains a vast compendium of summarized research on learning across the disciplines of life science, physical science, and Earth and space science.

For those who persevered, their efforts paid off in gaining clarity about the standards and how they relate to teaching and learning, but it took a substantial time commitment and their searches often ended when they identified learning goals for their particular grade span. As advocated by Project 2061 of the American Association for the Advancement of Science (AAAS), all teachers need a broad and deep understanding of all science topics. They should know what every twelfth-grade graduate is expected to know and the level of schooling in which students are expected to learn certain ideas in science. They should understand not only the learning goals at each grade span, but also the research suggesting what is difficult or easy for students to learn, the contexts and strategies that support learning, the connections within and across science topics, and how a coherent understanding grows over the K–12 sequence. But how do teachers develop this knowledge? Where can they find the tools and the time? CTS provides the means and the organized process to help education professionals use these professional publications efficiently and effectively. Most important, it has gotten the books off the shelf and into the hands of teachers so they could use them. The CTS Project identified 147 relevant curriculum topics and prescreened and identified all the readings from the resource books that would contribute to a teacher's understanding of the professional knowledge described above. These readings are combined in study guides and facilitated through a process that engages teachers in a deep and thoughtful study of teaching and learning connected to a curricular topic they teach.

In our experience introducing CTS to teachers, familiarity with and access to the CTS resources tended to be more on the side of the standards documents than the research. Teachers seemed to have less familiarity with and access to the research base on student learning. We know from cognitive research that students often have strong preconceptions about the world around them that may support or interfere with their learning (Bransford, Brown, & Cocking, 2000; Donovan & Bransford, 2005; National Research Council, 2007). For example, Driver et al. (1994) reported that several researchers have studied student ideas about "gas and found that, initially, [students] do not appear to be aware that air and other gases possess material character. For example, although young children said that air and smoke exist, they regard such material as having transient characters similar to that of thoughts" (p. 80). Even when students develop an awareness of the material character of gases, they still may not think of gases as having weight or mass. Until students understand that gases have mass, they are "unlikely to conserve mass when describing chemical changes that involve gases" (p. 77). In the past, teachers were either not aware of such misconceptions or were not prepared to identify and address them in their instruction. Teachers must know that their students may have these difficulties and understand the importance of helping young children see that "air is there." Brooks and Driver (1989) pointed out that by understanding the research, teachers of different grade levels would know how to focus their instruction on building understanding for children of different age groups. These teachers would know that five- to seven-year-olds can develop an understanding of air existing all around them and moving naturally by observing windy days, effects of moving air on objects such as streamers and parachutes and can begin to see that we can make air move by sucking and blowing and that air takes up space through balloons or can be "squashed" by observing squeeze bottles. Seven- through eleven-year-olds learn that air occupies space, has mass and therefore weight, and pushes out in all directions by observing bubbles in water, balloons, and inflating tires. This paves the way for eleven- through fourteen-year-olds to learn that air can be compressed and expanded and to develop understanding of atmospheric pressure. All of these ideas are encompassed either explicitly or implicitly in the state standards teachers and students are held accountable for achieving. By using CTS, teachers can identify key ideas in their standards and then refer to research summaries to know what may make the learning difficult or comprehensible to students. They can use this information to plan instruction at their own grade level or comprehensively across grade levels. They now have a way to access and link the research to K–12 student learning goals.

BUILDING PROFESSIONAL COMMUNITY

The other underlying belief that is changing teacher professional development for the better is the growing commitment to building PLCs among teachers. After more than a century of schools that operated like multiple one-room schoolhouses under one roof, the idea of a PLC and teamwork in schools is finally taking hold. In the recent past, teachers across the hall or just next door may have been struggling with the same questions and problems with no reason or way to collaborate to find solutions. Increasingly, teaching is being deprivatized by the growing number of PLCs in schools that examine practice and results on a regular basis and pursue solutions to the problem of poor student performance. However, like other innovations, building a PLC doesn't happen by magic, and there are many pitfalls that must be addressed. In our work, we have focused on putting the "professional" into the PLC. We have asked, "What are the tools teachers need to make sure they reflect the knowledge of the profession in their learning communities?" Our conclusions are that PLCs must be research-based and standards-driven to be "professional." Historically, isolation among teachers led to very little sharing of what works among educators. Recent technologies and new organizational structures are helping to change that. Yet teachers' days are still highly structured and scheduled and they need efficient and effective ways to work together and put their professional knowledge to work. Through CTS, once teachers learn the process, they can quickly and efficiently explore the readings on any given science topic to address questions of practice and inform deliberations and decisions for their own practice and to share with others in their PLCs. Whether they are involved in a formal PLC that meets to examine results and pinpoint areas for improved student learning, or a grade level team monitoring how new curriculum materials are working, the CTS process will support and enhance these collegial groups of teachers to use the research and the standards to inform their work. Through the use of CTS, we have seen the conversations in these groups shift from the autobiographical stories that emanate from, "What are you doing in your classroom?" to scholarly discussions that pertain to all teachers such as "What do the national standards and research say, and how might we apply that in our classrooms and to the implementation of our state standards?" Examinations of curricular or instructional strategies are enriched because teachers base their analyses on whether the materials and strategies reflect important and challenging key ideas and research on how children learn as opposed to focusing only on their own opinions, biases, or the materials' style, layout, or reading level.

As schools and school districts support new organizational arrangements that reduce hierarchy and promote collaboration, CTS can help at every juncture. As Ann Jolly, a former middle school science teacher and an Alabama Teacher of the Year reports,

> PLCs involve teams of teachers in working together to study, learn, and support one another as they make changes in classroom practice. The process is collaborative rather than isolated. Ongoing learning and support continue throughout the school year. This professional development occurs at the school site and focuses on needs of the specific students in that school. Teachers work as interdependent colleagues, and a culture of collaboration and collective responsibility takes root. When teachers work together in PLCs to implement new teaching practices, over 90% of teachers do so successfully. Teamwork and collaboration work! (Jolly, 2007, ¶ 8)

PLCs are usually organized as collaborative teacher groups focused on learning and achieving desired results. Eaker, DuFour, and Burnette (2002) suggested that PLCs systematically address four key learning questions:

1. What do we want students to learn?
2. How will we know if they have learned it?
3. What do student-learning data reveal?
4. What are we going to do if students are not learning?

Too often, however, these collaborative groups lack a systematic focus on disciplinary content or lack the knowledge base on learning science to adequately address these questions. Table 1.2 shows how the CTS process and specific sections of the study guides in the CTS parent book can be used to address these questions. Beginning with the first question, CTS can guide the school community to ensure that the science learning objectives the group chooses are enduring and that important ideas reflected in the national standards are clarified so that key ideas are clear and explicit and supported developmentally and conceptually by research. In addressing the second and third questions, CTS can also help the community use assessments that probe for understanding by using the CTS process to develop and use ongoing formative assessments that link key ideas in the standards to common misconceptions and reveal whether students have similar ideas to those identified in the research. Teachers examine students' results on assessments that reveal their thinking to decide what is needed next. The fourth question may be answered by examining the K–12 articulation of learning goals to determine whether gaps exist that may pose barriers to learning, by analyzing curriculum materials to see the extent to which they promote learning of the key ideas, by identifying instructional contexts or phenomena that have proven effective in supporting learning, or even by examining teachers' own content knowledge to determine whether they are making the right connections. Table 1.2 shows how the different sections of the CTS process can support key questions for PLCs. (For a refresher on the six different sections of a CTS guide and the resources that are used with the sections, turn to page 22 in the CTS parent book or refer to Handout A1.6: Anatomy of a Study Guide in the Chapter 4 folder of the CD-ROM for this *Leader's Guide*.)

Table 1.2 Key Questions for PLCs and How CTS Can Help

Key Question	*PLC Use of CTS*
What do we want students to learn about a particular science topic?	• *CTS Section III, V, and VI*: Identify the learning goals that align with the topic; unpack the concepts, ideas, or skills within the learning goals for the topic. • *CTS Section V*: Identify the connections among related concepts; examine how key ideas build. • *CTS Section I*: Examine the culmination of K–12 science literacy ideas for enduring understanding and use into adulthood.
How will we know if they have learned it?	• *CTS Section IV*: Identify common misconceptions that may be revealed through instruction and assessment. • *CTS Sections III, IV, and VI*: Develop and use formative assessments and culminating performance tasks to check for understanding before, throughout, and at the end of instruction.

Key Question	*PLC Use of CTS*
What does the student learning data reveal?	• *CTS Section III*: Identify the extent to which students' ideas match the key ideas in the standards. • *CTS Section IV*: Identify common misconceptions and barriers that impede learning.
What are we going to do if they do not learn?	• *CTS Section II*: Examine instructional contexts and suggestions to determine if curricular or instructional changes are needed. • *CTS Section IV*: Examine ways to address student misconceptions. • *CTS Section V*: Examine the K–12 articulation of learning goals to see if there are gaps that need to be filled; look for ways to make stronger connections among a coherent set of learning goals.

OBSERVATIONS AND VOICES FROM THE FIELD

The results of using CTS have been impressive. (*Note:* The final summative evaluation of the CTS Project will be available on the CTS Web site in 2010.) As one teacher leader who used CTS said, "The process is an essential tool to bridge the gap between research- and standards-based practice in teaching science." A mentor teacher reported that CTS is especially useful in situations where mentors work with novice teachers and that the novice teachers are not the only beneficiaries. She described how mentors also show tremendous growth in skills and understandings when they use CTS as part of an induction program for beginning teachers.

Many users have commented on the ease and versatility of the CTS materials. For example, one participant said, "The [materials] allowed for a directed view of where to look in the CTS guides for the information we needed." Another pointed out that "developing our own [assessment] probes helped to give insight into what it takes to develop a good formative assessment item that can uncover the misconceptions our students have."

One of the greatest results we have seen comes from the teacher "aha" moments. For example, one leader reported this insight:

> I was sitting with some 8th grade science teachers when one of them turned to me and said, "I can't believe it, I'm not teaching what I am supposed to be teaching!" That went on in various forms throughout the two days with the math and science teachers. CTS really had the teachers looking intently at what their students needed to know on a topic. They were clearly dissecting the standards. Not only did they dig in but their vocabulary changed.

As another teacher commented, "The most valuable aspect of CTS was finding out what I need to know to be scientifically literate in order to teach content."

Teachers have pointed out that another valuable aspect of CTS for them is the review and discussion of misconceptions and misunderstanding based on research. As one teacher said, "It's a 'wake-up call' to all teachers that instruction strategies/techniques that address misconceptions are keys to learning."

One professional developer we worked with summed up the value of CTS this way:

> CTS is a systematic procedure anyone can use; it provides synthesized information on specific topics and thus saves time in looking for answers; it helps users work from a common understanding of a particular topic to answer a specific question; and it helps users develop the habits of good research strategies.

After experiencing CTS, leaders of professional development for science teachers immediately saw the significance of using CTS to enrich and invigorate teacher-learning programs. Many professional developers in science are not experts in every science topic area. Some with excellent backgrounds in one science area, such as Earth science, may be responsible for designing teacher learning programs in all other science domains including physical, life, and space science. They need an easily accessible process for gaining a clear vision of the important science for the K–12 classrooms and how to translate that science into grade level–appropriate curriculum and instruction. CTS provides such a tool.

PROFESSIONAL DEVELOPMENT DESIGNS ARE ENHANCED THROUGH CTS

Professional development for science teachers comes in a variety of forms and structures ranging from half-day workshops to weeklong institutes, to ongoing collaborative structures like PLCs and lesson study. Regardless of the type or length of the professional development experience, CTS increases the focus on the content by connecting it to the key ideas in the standards and the research on learning. This increased focus ultimately translates into improved student achievement. For example, leaders who are instructional coaches should routinely do a CTS on the topics they are addressing in their coaching. Sometimes these leaders use this information for their own planning, but more often they incorporate it into the work they do with teachers, such as collaboratively planning and providing feedback on a lesson together. In Chapter 7, you will find examples of professional development where the leader uses CTS with teachers in the context of particular professional development strategies. CTS is so valuable for leaders, we believe that no professional development leader should plan content-focused workshops, study groups, lesson study, or any science professional development without first doing a CTS on the topics they will address in their professional development session. This book contains all the tools and resources to support them not only to do that, but also to build in rich CTS experiences for the teachers with whom they work to improve science education.

CTS is a versatile resource designed to address multiple needs, audiences, and contexts. Likewise, this *Leader's Guide* addresses the multifaceted nature of professional learning and the different types of leaders who may design and support teacher learning by using CTS. To give you a sense of the versatility of CTS when it is used within different contexts, the following are just a few examples of the various ways leaders use CTS. They also show how the CTS underlying beliefs of building specialized knowledge of science teaching and learning, as well as supporting collaborative group learning, are manifested through these examples.

CTS USE BY COLLABORATIVE SCHOOL TEAMS

Student learning is at the heart of what teachers do. When teachers encounter students having learning difficulties, one reaction has been to simply teach the content over again in the same or slightly different way. Another approach is to gather data to find out what the students are having difficulty understanding and if other teachers at the same grade level are experiencing similar results. In this second approach, CTS resources help to pinpoint how to make the content more accessible to students. Improving opportunities for students to learn science content by first examining teachers' own content knowledge, identifying key ideas they want their students to learn, identifying instructional contexts that can enhance learning, becoming aware of the research on students' ideas in science and how they impact learning, and understanding how learning progresses from one idea to the next in a coherent sequence of ideas improve both the quality of teaching and subsequently the depth and endurance of learning.

For example, a middle school team might observe that their students seem to perform poorly on assessment items measuring inquiry skills on the state test. The teachers wonder what they can do to improve students' abilities to design and carry out a scientific experiment. Although their students have had opportunities to experience science in a hands-on learning environment, the students always score low on the inquiry section, especially experimental design that involves controlling variables. The team decides to use the Experimental Design CTS module (see Chapter 5) to investigate the topic. During the CTS process, they define for themselves what an experiment is and how it differs from other forms of investigation. Several of the teachers on the team had thought all investigations were experiments and the CTS helps them understand the various ways scientists investigate the natural world, including experimentation. Furthermore the team had not been aware that the research indicated how difficult it is for students to identify and control variables.

After using the instructional scaffold activity in the Experimental Design CTS module, the teachers understand how important it is to explicitly scaffold and teach students how to identify and control variables. As they use the *Atlas of Science Literacy* (AAAS, 2000, 2007), they become more aware of the precursor skills and knowledge that build up to students' being able to design their own experiments and know why identifying and controlling variables are important to scientists. Overall, the CTS helps the team understand why their instruction hadn't been working for their students and what they need to do so that their students can achieve the targeted learning goals. As a group, they revisit their curriculum and instructional materials and strengthen them. The conversation shifts in the team from an activity focus to a learning focus, guided by the common knowledge base they now have as a team as a result of doing the CTS together.

CTS USE IN PRESERVICE EDUCATION

Preservice teachers in science education courses benefit tremendously from using CTS at the beginning of their careers. Not only does it establish a habit of practice that will be useful to them throughout all stages of their careers, but it also helps them link their preservice experiences to the current emphasis in many schools on standards and research-informed instruction. For example, most preservice teachers are asked to design at least one lesson as part of their methods course requirements. CTS provides the information they need up front to ensure their lesson appropriately addresses important key ideas in science and anticipates the commonly held ideas students might bring to their learning. CTS creates the awareness needed for preservice teachers to design effective lessons that address standards and are informed by research on learning. In the process, many preservice teachers, particularly those who have limited science backgrounds, find they are gaining new knowledge about content, teaching, and learning and realize areas where they would like to continue their science content learning. It also brings a deep appreciation early on in their careers of the need to have and use a professional library of resources that will help them teach in a system that increasingly focuses on accountability to standards and instructional decisions based on research.

CTS ENHANCES SCIENCE EDUCATION LEADERSHIP

CTS has many benefits for people in science education leadership roles, such as school and district administrators, teacher leaders, and coaches. In our CTS work, we encourage all leaders working in these roles to use CTS to increase their familiarity with science standards and learning research and how they are used to inform curriculum, instruction, and assessment. Depending on one's role, these leaders may need more in-depth understanding of the key ideas in the learning goals and the commonly held ideas noted in the research on learning in any particular grade spans.

District Science Coordinators

For example, district science coordinators are often responsible for curriculum adoption and development committees, overseeing and supporting coaches, arranging and approving professional development in science, making classroom observations, requesting resources and lab materials and related tasks that require them to have a very broad and deep understanding of K–12 science. Very often they may be a specialist in one particular area of science (e.g., high school chemistry), but may not have firsthand knowledge about what learning strategies are effective for teaching basic life science topics in Grade 4 or the common difficulties students have with key ideas in astronomy. They can benefit from engaging in full curriculum topic studies on topics that are the focus of new curriculum, to inform the selection of professional development programs and to make a research-based case for using certain materials and labs. Every science coordinator should own a copy of the CTS parent book and all of its accompanying resource books listed in Table 1.1. They should actively share these books with the people with whom they work to encourage others to use CTS to inform teaching actions and decisions.

Principals

Programs for principals can use CTS to help prospective school administrators develop an understanding of what they should look for when teachers are teaching certain science topics. For example, one principal said he was wondering why a teacher he observed had been asking her students questions about content that was not directly addressed in the lesson being taught, and he noted it in the evaluation as a concern. After the lesson, he asked the teacher about it. She shared with him that she had a hunch that students were missing some of the prior knowledge needed to understand the topic she was teaching. She pulled out a map from the *Atlas of Science Literacy* (AAAS, 2000, 2007) and showed the principal the concepts and specific ideas that students are expected to develop at each grade level and pointed out the areas in which she was probing students to see if they had the prior knowledge that served as a precursor to the ideas she was trying to develop in her lesson. She showed him the CTS guide that indicated which *Atlas* map to use to examine the topic she was teaching. The principal developed a greater appreciation for what this teacher was doing to assess prior knowledge and quickly saw how using CTS himself would inform his classroom observations. While principals do not have to know every bit of information on the 147 science topics included in the CTS parent book, it is important for them to experience CTS enough so that they know its purpose and can suggest teachers use it as they are planning lessons, developing assessments, and reviewing the essential content students should learn. In addition, administrators should encourage teachers to use CTS to justify decisions they make regarding teaching and learning.

Teacher Leaders and Instructional Coaches

Teacher leaders and coaches are other key leadership groups that can strengthen and enhance their leadership capacity through CTS. Teacher leaders and coaches are often chosen because they stand out among peers and are successful with their own students. When they begin to work with a variety of teachers, they are challenged to know the goals for science learning across many grade levels, and they must be a resource for teachers who may be teaching topics at a grade level with which the coach or teacher leader is not familiar firsthand. CTS helps in both areas. When leaders use CTS themselves, they can quickly and efficiently review the standards and research to inform what they do to support their teachers. They can also introduce CTS tools to the teachers with whom they work so they have access to the information they need any time. It is like having a virtual expert on call any time the coach, mentor, or teacher leader is not readily available to provide assistance.

THE LANGUAGE OF CTS

Like any new tool or resource, CTS comes with its own language, specialized terminology, and operational definitions. For the purpose of clarity, Table 1.3 lists words and terms frequently used throughout this *Leader's Guide*. Descriptions of how this terminology is used in the context of CTS, as well as operational definitions for words that may have different meanings in other contexts, is provided for leaders to ensure consistency when using CTS in your professional development contexts. In addition, this chart is provided as Handout 1.1 in the Chapter 1 folder on the CD-ROM at the back of this book if you choose to share it with teachers, adapt it, or add additional terminology you use in your CTS professional development.

Chapters 1 and 2 in the CTS parent book introduce the user to CTS and the tools and collective resources used with the process. In Chapter 2 of this *Leader's Guide*, we will expand upon these two chapters by describing what leaders need to know to introduce CTS effectively in their work with science educators.

Table 1.3 CTS Specialized Terminology

CTS Terminology	*Clarification of Terminology Used in the CTS Context*
Commonly held idea	A pervasive notion about a scientific idea that has been studied in groups of students with results published in the research literature and is likely to be held by students outside of the study
Concept	A mental construct used to conceptualize a scientific idea (e.g., gravity, space between molecules, interaction in a food web)
Content knowledge	Knowledge of disciplinary subject matter (e.g., physical science, astronomy, nature of science, inquiry, etc.)
CTS	An acronym that stands for curriculum topic study
CTS Learning Cycle	An instructional model for CTS adult learning
CTS parent book	A shorthand way of referring to the book, *Science Curriculum Topic Study: Bridging the Gap Between Research and Practice* (Keeley, 2005)
Grain size	How broad or specific a topic is (e.g., *properties of matter* is a large grain size topic whereas *density* is a small grain size topic)
Key idea	An important idea unpacked from a learning goal—sometimes there are several key ideas embedded in one learning goal
Leader's Guide	A shorthand way of referring to this book, *A Leader's Guide to Science Curriculum Topic Study*
Learning goal	A teaching and learning target that specifically describes what students should know or be able to do
Misconception	A catch-all term for ideas students have that are not entirely scientifically correct (e.g., naïve ideas, partial understandings, preconceptions, misunderstandings, alternative frameworks)
National standards	Both the *Benchmarks for Science Literacy* and the *National Science Education Standards*
PCK	An acronym that stands for pedagogical content knowledge—this is the specialized knowledge about science teaching and learning that teachers need to understand in order to make content accessible to students
Preconception	An idea formed, often early on, before students formally encounter the content. Preconceptions can form outside of school or during previous curricular contexts
Professional learning community (PLC)	A group of team members who regularly collaborate to make improvements in meeting student learning needs through a shared vision and focus on curriculum, instruction, and assessment
Research	Although there are many kinds of research in education, in CTS, this term refers specifically to cognitive research (research on learning)
Science literacy	The understandings and ways of thinking that are essential for all citizens in a world shaped by science and technology (AAAS, 1989)
Skill	A process skill used in science (e.g., measurement, explanation, controlling variables) or a habit of mind (e.g., critical reasoning, skepticism, identifying bias)

CTS Terminology	*Clarification of Terminology Used in the CTS Context*
Sophistication	The complexity of an idea at a given grade level; for example, the Grades 3–5 gravity key idea that "The Earth's gravity pulls any object toward it without touching it" is at a lower level of sophistication than the Grades 6–8 idea that introduces the notion of a gravitational force between objects that depends on the mass of the objects and how far apart they are from each other
Standards	Common goals established nationally, statewide, or locally that are widely accepted by the science community and provide a focus for teaching and learning
Study guide	One of the 147 CTS study guides
Teacher educator	Anyone who facilitates teacher learning such as preservice faculty, scientists working with teachers, staff developers, coaches, etc.
Topic	A conceptual organizer or category for related learning goals that can be taught in a variety of contexts or themes (e.g., *life cycles* is a CTS topic, but *life cycle of the butterfly* is a contextual theme)
Topic study	A shorthand way of referring to a curriculum topic study