

Preface

OVERVIEW OF THE CTS PROJECT

Curriculum Topic Study (CTS) is a National Science Foundation–funded project that developed a process, guidelines, and materials for K–12 educators to deepen their understanding of the important science and mathematics topics they teach. CTS builds a bridge between state and national standards, research on students’ ideas in science and mathematics, and opportunities for students to learn science and mathematics through improved teacher practice. Principal Investigator Page Keeley, of the Maine Mathematics and Science Alliance, directed the project, in collaboration with Co-Principal Investigator Susan Mundry, from WestEd.

The CTS process, tools, and materials engage educators in a systematic and scholarly method of using national and state standards documents and research summaries on student learning to study a curricular topic; analyze findings from the study; and apply the new knowledge gained about content, curriculum, instruction, and assessment to teaching and learning. Rather than providing the answers, CTS promotes inquiry among educators by guiding them in discovering new ideas about teaching and learning connected to the curricular topics they teach.

The four books resulting from the project include *Science Curriculum Topic Study: Bridging the Gap Between Standards and Practice* (Keeley, 2005); *Mathematics Curriculum Topic Study: Bridging the Gap Between Standards and Practice* (Keeley & Rose, 2006); this book, *A Leader’s Guide to Science Curriculum Topic Study*; and *A Leader’s Guide for Mathematics Curriculum Topic Study* (2010 anticipated release). In addition to the four books, there is a Web site that provides updates on the project and supplementary materials to support CTS. The URL for the Web site is www.curriculumtopicstudy.org.

THE KNOWLEDGE BASE THAT INFORMED CTS

There has never been a greater need for students to learn and excel in science. Our future society will increasingly be highly technological and scientific, yet recent reports warn that many U.S. students are not being adequately prepared to contribute to an increasingly scientific and technological workplace. As the Committee on Science Learning K–8th Grade recently wrote,

We are underestimating what young children are capable of as students of science—the bar is almost always set too low. Moreover, the current organization of science curriculum and instruction does not provide the kind of support for science learning that results in deep understanding of scientific ideas and an ability to engage in the practices of science. (National Research Council [NRC], 2007, p. vii)

Recent results from an international assessment of students' understanding in science and the ability to use scientific knowledge to address questions and solve problems in daily life (Programme for International Student Assessment [PISA], 2007) shows U.S. students lagging behind many of their counterparts in other nations. Educators are increasingly being called on to use research-based practice and to adopt methods that support all students to reach challenging learning outcomes in science. Experienced teachers with strong backgrounds in science subject matter and extensive pedagogical content knowledge may be our very best hope for supporting student learning and interest in science. Pedagogical content knowledge (PCK) is the specialized knowledge about teaching and learning that helps teachers understand what makes the learning of specific topics easy or difficult for students and develop strategies for representing and formulating subject matter to make it accessible to learners (Shulman, 1986). Teachers with background knowledge in subject matter content and specialized knowledge of teaching science tend to produce higher achievement outcomes among their students (Darling-Hammond, 2000; Goldhaber & Brewer, 2000; Monk, 1994). Research on professional development programs in science and mathematics shows greater positive effects on student learning from programs that focus on building teachers' content knowledge and on understanding of how students learn subject matter (Brown, Smith, & Stein, 1996; Cohen & Hill, 2000; Kennedy, 1999; Weiss, Pasley, Smith, Banilower, & Heck, 2003; Wiley & Yoon, 1995). That is why effective teacher professional development in science must not only address the content teachers need to know in order to successfully teach developmentally and conceptually appropriate ideas and skills at their grade level; it must also be designed to help teachers understand how to best identify, organize, and teach important content.

The National Science Education Standards make a strong argument for why we need tools that help teachers develop PCK.

Effective teaching requires that teachers know what students of certain ages are likely to know, understand, and be able to do; what they will learn quickly; and what will be a struggle. Teachers of science need to anticipate typical misunderstandings and to judge the appropriateness of concepts for the developmental level of their students. In addition, teachers of science must develop understanding of how students with different learning styles, abilities, and interests learn science. Teachers use all of that knowledge to make effective decisions about learning objectives, teaching strategies, assessment tasks, and curriculum materials. (NRC, 1996, p. 62)

CTS was developed to provide tools that help teachers develop this type of specialized science teacher knowledge.

PURPOSE OF THIS BOOK

All of the above describe why CTS is an important process for teachers to learn and use. In 2005, the CTS parent book, *Science Curriculum Topic Study: Bridging the Gap Between Standards and Practice* (Keeley, 2005), was published. It provides the introduction, process, and material teachers need to conduct a curriculum topic study. The purpose of this book is to support leaders in facilitating the CTS process and applications. It offers designs and suggestions using CTS in a variety of professional development configurations to improve teachers' content knowledge and various aspects of their curricular, instructional, and assessment work.

Furthermore, this guide is designed to strengthen the ways national standards and research on learning are embedded within effective professional development strategies. This *Leader's Guide* is designed to provide leaders with a standards- and research-based “tool box” filled with a variety of content-specific professional development designs, tools, and resources that will strengthen professional development and help educators become more effective teachers of science.

AUDIENCES

The primary audiences for this book include the many professionals who lead or support teacher professional development and preservice education in science in grades K–16. These include national, regional, and local science professional developers; science teacher leaders; coaches and teachers on special assignment; facilitators of professional learning communities (PLCs); state and local science specialists and supervisors; staff from school-university partnerships, including science education faculty in schools of education, science faculty in schools of arts and sciences, district-based science teachers, and faculty and student-teacher supervisors in teacher education programs; and university faculty who teach science methods courses in teacher preparation programs. All of these primary audiences can use this resource book to enhance their own teaching and provide courses, workshops, institutes, and other professional development experiences for current and future science teachers.

Secondary audiences include principals; district curriculum and assessment coordinators; informal science specialists who design and implement informal programs for K–12 students and adult consumers of science; and curriculum and assessment developers, who can all use the book as a resource to strengthen the science programs in their schools, improve the effectiveness of committee work, and increase teachers' understanding of the research on science teaching and the most important science concepts they need to teach in K–12 to improve learning results.

THE NEED FOR CTS IN PROFESSIONAL DEVELOPMENT

The CTS approach to professional development that is the subject of this book is designed to enhance teachers' understanding of the science content that is most important for all students to learn and how to improve students' opportunities to learn the content through effective curriculum, instruction, and assessment. CTS provides educators with processes, tools, and resources to link content standards and the research on learning to classroom practice. Classroom practice includes teachers' content knowledge, the curriculum or instructional materials they use, instructional contexts and strategies, and uses of assessment. CTS provides a powerful yet simple way for science educators to engage in professional development that will help them

- enhance their adult science literacy,
- explore implications for effective instruction,
- identify the key ideas and skills students need to progress through their K–12 learning,
- use research on students' ideas in science to inform teaching,
- recognize connections within and across topics in science, and
- be a better consumer of their state standards and district curriculum.

CTS is a valuable resource for leaders and designers of teacher learning in a variety of settings ranging from one- or multiday workshops, to weeklong institutes, to semester preservice and graduate courses, to PLCs that meet regularly over a year or more. Over the past decade or so, professional development in science has been undergoing a transformation from primarily “one size fits all” workshops and field experiences to more ongoing, subject- and need-focused programs, often situated in teachers’ real work, such as through examining student work, reviewing and selecting instructional materials, developing exemplary lessons, and coaching and mentoring (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010; Sparks, 2002). These new forms of professional development have come about as the field has gained a deeper understanding of how people learn and begun to seek ways to embed teacher learning in their real work. However, a major challenge to making these forms of professional development work is ensuring that the teachers and facilitators have tools to focus this work on the appropriate K–12 content and how to teach and assess it effectively. For example, we have seen many groups coming together to examine student work with insufficient content knowledge, a lack of knowledge about students’ ideas that provides a lens for identifying misconceptions and learning difficulties, and inconsistent interpretations of the meaning and intent of the learning goal being assessed. Furthermore, the protocols needed to support teachers to learn from their professional development experience and make productive decisions about using what they learn in the classroom were often missing or ineffective.

This *Leader’s Guide* was developed to bring the content-specific knowledge of teaching and learning science into the center of the many “new” more building-based or job-embedded professional development strategies, such as looking at student work. It provides guidelines and structure for facilitators to engage teachers in evidence-based dialogue, supported by standards and research on learning. For example, a facilitator’s use of CTS can enhance a group’s collegial learning in contexts such as looking at student work by first engaging the teachers in answering key questions such as the following:

- What should the students in this grade be expected to know about this topic?
- What common misunderstandings do children of this age group tend to have?
- What prior knowledge is necessary to support the understanding of this topic?
- Is there content you are unsure about that you would like to learn more about in order to interpret student responses?

This information provides teachers with a stronger foundation for looking at their students’ work and connecting it to key ideas in the standards and the research on how students think about the key ideas. Furthermore, it strengthens facilitators’ ability to lead a group through the process by enhancing their knowledge.

BRIDGING THE GAP

The CTS project set out to increase the use and application of national standards and research in the classroom and in professional development for teachers. The four major national standards publications that guided the development of state standards and curriculum frameworks—*Science for All Americans* (American Association for the Advancement of Science [AAAS], 1989); *Benchmarks for Science Literacy* (AAAS, 1993), including published summaries of research on learning in Chapter 15; *National Science Education Standards* (NRC, 1996); and *Atlas of Science Literacy* (Vols. 1–2) (AAAS, 2001–2007)—along with the research compendium, *Making Sense of Secondary Science* (Driver, Squires,

Rushworth, & Wood-Robinson, 1994), collectively provide educators with a rich professional knowledge base. This knowledge base includes the key ideas and skills needed for science literacy, commonly held ideas students bring to their learning, contexts and implications for instruction, conceptual difficulties and developmental implications for learning, and the coherent growth of learning from kindergarten to high school graduation. These publications have been available to teachers since the start of standards-based reform in the mid-1990s. Yet through the hundreds of CTS workshops the authors have given and observed, the majority of teachers who are first introduced to CTS indicate they have never used these resources. Every introductory CTS workshop we piloted began with an overview of the national standards and research publications listed above, followed by a show of hands when the following questions were asked: "How many of you have heard of or own this book and use it? How many of you have heard of or own this book but have never used it? How many of you are hearing about and seeing this book for the first time?" Most surprising is the number of hands that still go up when the last question is asked. This lack of use of the professional publications that form the backbone of standards- and research-based teaching and learning is further amplified in studies such as the NRC's 2002 report, *Investigating the Influence of Standards*. A conclusion of this report was that although they have been out for almost a decade, standards have not made a significant impact where they matter most: in the classroom.

Furthermore, new teachers are now entering the profession who were middle school students at the time standards were introduced. Career changers are also entering the profession as new teachers. They missed the 1990s wave of learning about standards while they were working in noneducation fields. During the 1990s and early part of the twenty-first century, today's experienced teachers were introduced to standards and the basic principles of standards-based reform. For almost a decade, they were immersed in a flurry of activities such as alignment of curriculum, backwards planning for standards-based lessons, and development of aligned assessments. While the attention to standards has subsided somewhat as teachers developed familiarity and acceptance of standards, we still need to acknowledge that new teachers, both young and career changers, entering teaching today did not have the introduction to standards that our experienced teachers did. Today standards are almost taken for granted. However, that doesn't mean that experienced teachers are using them effectively. In addition, teachers outside of a university setting have not easily accessed the research. Clearly we still have many more years ahead of us to reach the level of implementation where all teachers are effectively focusing on standards and using research to inform their teaching.

Translating the standards and research into practical use in the classroom is a continuing challenge for science education reform. The materials developed by the CTS project are designed to support educators to meet this challenge. The developers of CTS realized that teachers needed both a reason to use the national standards and research on learning and an efficient process for working with them. Facilitators of teacher learning needed realistic designs and suggestions for how to engage teachers in new forms of professional development that lead them to identify and examine the various considerations that support science literacy learning for all students. CTS was developed to help teachers and professional developers methodically incorporate the standards and research into their work.

CTS began with identifying 147 key curricular topics in the standards and thoroughly vetting the common standards and research documents to identify the readings that could be used by teachers and professional developers to explore and study these key topics. Tools for applying the study results were developed, followed by designs for professional development that would embed CTS into a variety of teacher learning contexts.

IMPLICATIONS FOR PROFESSIONAL DEVELOPMENT

Finding time to stay abreast of the standards and research is difficult. A teacher's day is already jam-packed, and many legitimately ask, "Where can we find the time we need to learn all this?" The answer lies in making better use of existing professional development time and in engaging in learning about and using the standards and research in the regular school day. The authors believe every professional development experience—whether it is a content institute, an overview to new curriculum materials, a teacher-directed study group, grade-level team meetings to examine student work, or others—is a ripe opportunity to use CTS. The current trend to providing more substantive and ongoing professional development and forming learning communities is transforming what and how teachers learn, yet it is essential that these new forms of professional development focus on important content and how to teach it (Feger & Arruda, 2008; Hord & Sommers, 2008; Loucks-Horsley et al., 2010; Wei, Darling-Hammond, Andree, Richardson, & Orphanos, 2009).

The CTS process provides the resources that link the theoretical knowledge that comes from a careful examination of standards and research to the situations teachers face in their schools and classrooms. It is this situated use of CTS that supports such a wide variety of strategies for teacher learning.

Studies have also shown that the types of professional development closely linked to improved student learning provide opportunities for teachers to engage in professional dialogue and critical reflection (Birman, Desimone, Garet, & Porter, 2000; Cohen & Hill, 1998; Weiss et al., 1999). Increasingly, professional development is focused on breaking down the isolation of teaching and building a professional culture in schools characterized by groups of teachers examining student results, thinking and reflecting on practice, discussing research and what works, and developing teacher leadership (Schmoker, 2004). The advantage of teachers working collaboratively and learning from their own practice is that teaching practice, aligned with clear and explicit student learning goals, becomes the centerpiece of the professional development. Teachers examine and critique actual artifacts of teaching and learning, such as lessons, student work, and cases of teaching and learning. CTS can provide the focus and direction collaborative groups need to advance their learning. Teachers in these groups learn to engage in authentic dialogue about the specific teaching and learning ideas in the standards and how these ideas compare with their own curriculum, instruction, and assessment. They analyze research on children's ideas and compare those to their own students' ideas. They look for ways to incorporate the research into their own curriculum and reflect on how to use this knowledge to enhance learning. For science teacher collaboration to be successful, it needs a strong content focus and well-developed skills for dialogue and reflection. CTS provides those critical elements.

CTS IMPACT ON TEACHERS AND TEACHER EDUCATORS

This *Leader's Guide* is designed to enhance teachers' and professional developers' knowledge and performance (e.g., strengthen content knowledge and support the design of content-rich professional development). In the science disciplines, teachers and professional developers are particularly challenged because even if they are knowledgeable in one science discipline or grade span, they may not know all the science disciplines or grade spans they are working with. CTS meets the diverse needs of a wide range of teachers and

leaders in science (e.g., the biologist who is teaching astronomy, the high school teacher leader who is working with elementary teachers on instructional strategies for first graders, or the university scientist codeveloping a middle school curriculum).

In working with teachers around the country, the CTS developers have documented the substantial impact the process has had on what teachers understand about science learning and how they approach their curriculum, instruction, and assessment. (A summative evaluation report of the CTS project will be available in spring 2010 at www.curriculumtopicstudy.org.) In the evaluation surveys and interviews, teachers who use CTS have reported that they

- deepen their understanding of the science content they need to teach K–12 curricular topics effectively;
- translate science content for adult learning (such as through university courses) to content appropriate for K–12 settings;
- identify and clarify core knowledge and skills in science including unifying themes, big ideas, concepts, skills and procedures, specific ideas, terminology, and formulas embedded in the content standards and curricular objectives;
- improve coherency of scientific ideas as they develop over multiple grade levels;
- make effective use of the research base on student learning to identify potential learning difficulties, developmental considerations, and misconceptions associated with a science curricular topic;
- apply effective content-specific pedagogical strategies and identify useful contexts for teaching scientific ideas as they relate to a particular topic;
- improve their ability to make connections within and across science topics; and
- engage in substantive evidence-based discourse with their colleagues about goals for student learning, modifications needed in instructional materials, and methods for enhancing student understanding.

Science leaders (teacher leaders, university faculty, professional developers, and science specialists) also benefit personally from using CTS. Leaders have commented that they have been able to increase the focus of the professional development on content and PCK and achieve greater results. For example, as part of engaging teachers in a science lesson, some professional developers now have teachers do a CTS on the topic of the lesson before they experience the lesson. This both enhances teachers' understanding of the important content and builds awareness of common preconceptions students might bring to their learning. By embedding CTS into their content institutes, scientists increase the opportunity for teachers to translate their content-learning experiences into developmentally and conceptually appropriate content and activities for the grade level they teach. This bridge between adult learning, often the "science of scientists," and K–12 student learning or "school science" has been missing from many of the professional content learning experiences designed for teachers by experts in a scientific field. These experts know their content well but are unfamiliar with PCK and "school science." CTS is the tool that leaders can use to help teachers situate their learning in the classrooms or other contexts in which they teach.

Leaders have also commented on the versatility of the materials and how they have been able to use them in a variety of situations including one-on-one coaching, PLCs, small informal teacher meetings, and large content institutes. While the materials may be used differently depending on where a teacher is on the teacher professional continuum, CTS adds value to every level of teaching from preservice to novice teachers to

experienced teachers to teacher leaders and to those who leave the teaching profession to support teachers. The process and the quality of the materials are helping all types of leaders in science education strengthen their work with teachers by focusing more precisely on standards and the research on students' ideas in science.

Ultimately the impact of CTS is demonstrated through the improved learning of students taught by teachers who regularly use the process to inform their teaching. These students benefit from higher levels of engagement due to teachers' understanding of how to make content accessible to all students. They also benefit from increased coherence in the use of curriculum materials and design of instruction as their teachers use CTS to identify gaps in the curriculum, select appropriate phenomena and representations, strengthen the connections among concepts, and use a variety of formative assessment techniques to elicit students' ideas and monitor learning throughout the course of instruction.

ORGANIZATION OF THIS BOOK

This *Leader's Guide* is organized into seven chapters. Chapter 1 provides the overall rationale for CTS, addresses the question, "Why should educators use CTS?" and introduces leaders to the language of CTS. Chapter 2 provides the leader with an understanding of what the CTS process is and discusses how it supports the development of science literacy. Chapter 3 is written especially for professional developers planning to use CTS in their work with teachers. It summarizes key information about research on effective professional development for science teachers and provides the overall tips and strategies for using CTS in professional development. Chapter 4 includes the designs to lead introductory sessions for CTS. If you are just getting started with CTS, you can use these designs to help your participants experience CTS by doing partial or full guided topic studies on several topics that will acquaint them with the process as well as the resources. Chapter 5 provides the designs and guidelines for leading full topic studies on particular topics (e.g., atoms and molecules), guidelines for designing your own full topic study, and suggestions for combining topics. Chapter 6 leads you through ways to use the applications of CTS in a content, curricular, instructional, or assessment context. Finally Chapter 7 discusses examples of how to embed CTS in ongoing professional development strategies, such as how to use CTS within lesson study, study groups, and mentoring. The CD-ROM contained in the back of this *Leader's Guide* provides masters for all handouts and PowerPoint presentations to accompany the introductory material in Chapters 1 through 3 as well as the designs and suggestions in Chapters 4 through 7.