Science Professional Learning Standards

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Council of State Science Supervisors

Professional Learning Committee

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Introduction

Content of Professional Learning Opportunities

All professional learning opportunities should prepare professional educators with the knowledge and skill to implement the three-dimensional vision of science learning presented in A Framework for K-12 Science Education.

To accomplish this aim, the principles of *A Framework for K-12 Science Education* should provide the basis for deciding upon and developing the content of professional learning opportunities in science. Each of these principles is grounded in the research on student learning presented in detail in the *Framework*.

Children are born investigators.

Educators at all levels elicit and make use of student ideas and student capacities for engaging in science and engineering practices in designing instruction.

Focusing on practices, crosscutting concepts, and core ideas.

Instruction is focused on a few core ideas, engages students in science and engineering practices, and helps students recognize crosscutting concepts relevant to different core ideas.

Understanding develops over time.

Educators structure opportunities for students to develop integrated understandings of disciplinary core ideas, science and engineering practices, and crosscutting concepts over a period of years, rather than weeks or months.

Science and engineering require both knowledge and practice.

Educators organize instruction to provide students with opportunities to develop an understanding of core ideas in ways that reflect the idea that science is both a body of knowledge and a set of practices used to establish, extend, and refine that knowledge.

Connecting to students' interests and experiences.

Classroom experiences are designed to connect with students' diverse interests, experiences, and identities.

Promoting equity.

Educators organize classroom activities that provide all students with opportunities to develop integrated understandings of disciplinary core ideas, science and engineering practices, and crosscutting concepts outlined in the *Framework.*

Science Professional Learning Standards

This document presents a set of Science Professional Learning Standards (SPLS) developed by the Council of State Science Supervisors.

Its purposes are:

- to help professional development providers design and implement high quality, sustained professional learning opportunities for teachers
- to provide guidance to state and local leaders about broad criteria they can apply to evaluate professional development plans and activities
- to empower teachers with a clear set of expectations for what kind of professional development opportunities should be available to them

Document Organization

The SPLS are organized into the three categories, as follows:

Attributes of High Quality Professional Learning Opportunities

Designs for professional learning opportunities should:

A1. Support educators to develop strategies for eliciting, interpreting, and making use of students' reasoning to inform their science instruction.

Elaboration: Developing students' science proficiency over time requires that educators attend carefully to the substance of students' thinking. Professional development can prepare educators to design tasks that elicit student ideas and interpret these ideas using learning progressions in science (Furtak & Heredia, in press; Furtak, Thompson, Braaten, & Windschitl, 2012). Helping educators develop content knowledge through recognizing patterns of student thinking can improve both teaching and learning outcomes (Heller, Daehler, Wong, Shinohara, & Miratrix, 2012). Designs for professional development can also prepare educators to use discussion to develop student ideas elicited from tasks and educator questions (Doubler, Carraher, Tobin, & Asbell-Clarke, 2011; Harris, Phillips, & Penuel, 2012; Minstrell & van Zee, 2003).

PD leaders:	**Teachers:**
Ask questions about teachers' prior knowledge regarding and experience with formative assessment strategies Integrate recommendations and present examples from NGSS and NRC Assessment report, particularly with respect to classroom assessment Introduce interpretive frameworks from research on student thinking to help guide interpretation of student thinking Provide tools and model strategies for classroom talk (e.g., "talk moves") Model contingent teaching -- meaning the PD goes differently depending on teacher needs Model reflection on activities where teachers have opportunities to practice in order to pull out important lessons from the activity Provide for reflection on the PD itself that can inform future PD	Discuss artifacts of student thinking and use learning progressions appendices / text in *Framework* to interpret these artifacts Design or adapt some artifact from their classroom (an assessment or follow-up lesson that is grounded in an analysis of student thinking) Practice strategies for leading discussions using talk moves Develop strategies for communicating assessment results with broader communities and stakeholders (including parents)

A2. Be sustained over a long duration and provide repeated opportunities to plan, implement, and reflect on instructional strategies in science classrooms that engage students in science and engineering practices.

Elaboration: Professional development that is of a long duration (two weeks or more) and sustained over time is associated with changes to educators' science instruction (Desimone, Porter, Garet, Yoon, & Birman, 2002; Penuel & Gallagher, 2009; Supovitz & Turner, 2000). One reason why educator professional development must be sustained over a long duration is that educators need time to try and reflect on new instructional strategies. Reflection on practice is a key component of effective professional development programs (Roth et al., 2011; Seidel, Stürmer, Blomberg, Kobarg, & Schwindt, 2011). Educators need opportunities to directly observe strategies that successfully engage students in practices. Evidence indicates that professional development that models practices for educators can help them to engage students in posing scientific questions, developing explanations, and constructing arguments (Harris et al., 2012; McNeill, 2009; McNeill & Knight, 2013; Simon, Erduran, & Osborne, 2006).

PD leaders:	**Teachers:**
Structure PD to provide for a cycle of teachers planning, implementing, reflecting on, and then revising strategies for engaging students in science and engineering practices Provide teachers with a structure to guide noticing and reflection on what happens when they try out things in the classroom and design for built in follow-up PD where teachers reflect and discuss these classroom experiences. Review evidence that indicates student learning and effectiveness of instructional strategies Provide teachers with opportunities to engage as learners in science and engineering practices, including the ways that practices "cascade" Provide teachers with opportunities to engage with videos and case studies of successful engagement of students in science and engineering practices in context of developing understanding of DCIs and CCCs Provide focused attention to science and engineering practices that are less commonly implemented (e.g., developing and using models) and how they can be integrated with DCIs and CCCs Develop and introduce templates to help teachers plan or adapt lessons that integrate the three dimensions of science learning	Decide on what evidence of student learning they will look for to determine effectiveness of strategies and how they will collect that evidence Elicit evidence of learning in their classrooms and reflect on that, to analyze what students are picking up, and assess success of the instructional strategies Use the strategies and knowledge learned in the professional development to create/adapt, implement, reflect on, and revise lesson plans that integrate three dimensions of science learning over multiple PD sessions Participating actively in science and engineering practices in context of developing explanations of a scientific phenomenon or engineering problem Analyzing their own experiences in professional development of how practices support learning of DCIs and CCCs

A3. Provide opportunities for school-level educator groups to discuss and coordinate efforts to design and implement coherent instruction across multiple years.

Elaboration: The learning progressions outlined in the framework span multiple years. Consequently, it is important that schools coordinate instruction across the years to provide students with opportunities to develop understanding over time. Research has documented a relationship between greater instructional coherence at the school level and higher student learning outcomes (Newmann, Smith, Allensworth, & Bryk, 2001). Coordination among faculty is key to design coherent curriculum and instruction that develops across years (Stein & Coburn, 2008).

PD leaders:	**Teachers:**
Provide framework for interpreting DCIs within a developmental framework (Learning Progressions) Structure PD so it is organized around specific DCIs by grade level the teachers are supposed to address, related to their location in the larger learning progressions in the *Framework*	Participate in professional learning communities PLCs that are structured across grade levels (fully met is a cross grade levels, but it may be grade-level for others) Use *Framework* progressions to coordinate design and implementation of coherent instruction across grade levels.

A4. Prepare educators to connect science learning with students' interests and experiences.

Elaboration: Relating instruction to students' interests and everyday experiences promotes student engagement, choice and agency in learning. Professional development experiences can provide educators with concrete strategies for building on students' cultural and community funds of knowledge to guide science investigations (Tzou & Bell, 2010). In addition, professional development can help prepare educators to give students greater agency, that is, choice and responsibility in planning investigations that address their questions (Morozov et al., 2014).

PD leaders:	**Teachers:**
Structure PD to include teacher investigations where teachers have choice and responsibility in planning and carrying out the investigations Model how to help students select phenomena to investigate that (also) meet PEs (Criteria for phenomena include: connection to a science story, data sets available) Identify and model scaleable strategies in PD that elicit teachers' interests and experiences and make connections to those interests and experiences.	Identify phenomena that will be interesting and relevant to students during instructional planning Implement instructional strategies to elicit students' interests and experiences and then connect those interests and experiences to science learning in the classroom Give students choice and responsibility in what research questions to address and in the planning and carrying out of investigations

A5. Integrate strategies that promote equitable participation in science learning for all learners.

Elaboration: Promoting equity requires that all students have full opportunity to learn science. Professional development can promote equity when providers have high expectations for all students' learning and prepare educators to engage students in all aspects of inquiry (Jeanpierre, Oberhauser, & Freeman, 2005). Educators may also benefit from learning an explicit set of "equity strategies" that promote full participation in classroom discourse (Michaels, O'Connor, & Resnick, 2008). Promoting equity entails paying explicit attention to historical inequities, which can help students identify with the enterprise of science (Bang & Medin, 2010).

PD leaders:	**Teachers:**
Motivating the teaching science: ● Importance of science for all ● Need for diversity in science (examples of specific contributions of scientists, places where science was overturned/shaped by addition of diverse perspectives -- "Who's Asking?") ● Idea that science and engineering often addresses human needs Model strategies for monitoring and achieving equity in participation and learning to ensure all students meet performance expectations	Understand how a common entry point (anchor) for science and engineering learning can provide a way for all students to engage with challenging DCIs, especially for students learning English Investigate ways to organize instruction to enable students to participate in science and engineering projects in their classrooms, schools, and local community (e.g., citizen science projects) Investigate opportunities to identify local scientists from diverse backgrounds with whom students can engage meaningfully Reflect on strategies for monitoring equity in participation and learning Select and plan for measures to use to monitor and achieve equity in participation and learning

A6. Model instructional strategies and curriculum materials that are consistent with the desired shifts in teaching and learning introduced in professional development.

Elaboration: Curriculum materials that embody visions for science learning and embed ways for educators to learn from them can help educators learn new instructional strategies (Davis & Krajcik, 2005; McNeill, 2009; Schneider & Krajcik, 2002). Professional development experiences that actively explore extant curriculum through investigation, problem solving, and discussion develops skills needed to effectively evaluate and adapt materials for their own classroom needs (Banilower, Heck, & Weiss, 2007). Providing educators with explicit strategies for adapting curriculum materials can help them to improve science teaching and learning (Penuel, Gallagher, & Moorthy, 2011).

PD leaders:	**Teachers:**
Model instructional strategies throughout the professional development. These strategies are: ● based on the findings of the research described in the NRC *Framework for K-12 Science Education and current research in teaching and learning science (e.g., students actively engage in science performances, students conceptualizing core ideas, students using models to communicate understanding.)* ● specific to teaching and learning for the curriculum materials participating teachers are using. ● presented within the context of the instructional materials that meet the state science standards. Demonstrate good alignment of PD and curriculum materials to NGSS and/or state standards Engage teachers in analyzing purposes of curriculum materials and how structures support purposes Engage teachers in a process of principled adaptation of instructional materials to meet students' needs, local environment, and available resources Focus on curriculum materials to which teachers have access. Focus on the grade levels that the teachers are responsible for teaching so they can implement those materials with their students Model how the instruction in the PD is translated into classroom practice	Engage in science performances that model authentic science teaching and learning. Analyze the purposes and organization of instructional activities and materials in the professional development Translate the instructional strategies in the PD into classroom instruction and/or lesson plans Use appropriate instructional materials from the PD in their own instruction and reflect on modifications to adapt the materials to meet their students' needs Modify the curriculum to meet the local needs and differentiate curriculum materials to meet their student needs or local environments

A7. Accommodate participants' varied levels of experience in supporting three-dimensional science teaching and learning.

Elaboration: No single format or model of professional development is likely to be effective for all educators along the professional continuum. Research indicates that educators with different levels of experience in implementing a reform differ in how they learn from professional development. Less-experienced educators may benefit most from intensive workshops, whereas educators with more implementation experience may learn more from opportunities to try new strategies in the classroom and discuss their efforts with colleagues (Frank, Zhao, Penuel, Ellefson, & Porter, 2011).

PD leaders:	**Teachers:**
Assess how much prior exposure to the *Framework* teachers have prior to PD Create common basic understandings of the *Framework* before all join in a PD, if there are varied levels of experience/expertise (e.g., online webinars, videos, articles and books) Provide PD that can be structured to reflect varied levels of experience with the *Framework* Model and practice a 3D approach to instruction and offer multiple strategies and offer templates/tools to evaluate the effectiveness of the model lesson Use strategies to ensure that there is equitable participation across experience levels (e.g., norms setting, grouping strategies) Engage in formative assessment to adjust to meet needs of participants Survey attitudinal shifts in teachers and students before and after implementation of greater integration of DCI, SEP and CCC	Participate actively in workshop preparation Identify what they expect students would exhibit in the classroom if they are learning with a 3D approach Try out different classroom strategies in the PD Meet with other educators over an extended period of time (e.g., in small groups or reconvene with the larger group over several sessions) to reflect on what worked and what didn't work in the classroom and to share ideas and learnings Utilize teacher-leaders to facilitate further dissemination of ideas, strategies, PD opportunities (at district or regional levels)

A8. Connect ideas and instructional strategies introduced during the professional development experiences to educators' current beliefs, instructional strategies, and goals for learning.

Elaboration: What educators' gain from professional development is shaped by their current beliefs about and knowledge of science teaching (Johnson, 2007). Educators' implementation of instructional strategies introduced during professional development is related to their judgments about how well those strategies fit with their instructional goals (Garet, Porter, Desimone, Birman, & Yoon, 2001; Penuel, Fishman, Yamaguchi, & Gallagher, 2007). Science teacher educators need to consider how to link new ideas and strategies to educators' prior knowledge and experience in high-quality professional learning experiences (Penuel, Phillips, & Harris, 2014).

PD leaders:	**Teachers:**
Build a vision collaboratively with PD teachers that sets a goal for learning and also a model for reflection Elicit teachers' prior knowledge and beliefs about science teaching methods Attend to differences between teachers' conceptions about instructional strategies and student learning and conceptions in the *Framework* Promote reflection on how instructional strategies modeled in the PD are similar to and different from teachers' existing strategies	Align goals for learning in science education in their classroom that embody the vision of the *Framework* Analyze their current instructional strategies as they compare to the vision of the *Framework* Reflect on the vision of teaching and learning in the *Framework,* gaps in their own understanding and practice, and what instructional strategies help them close those gaps

A9. Incorporate curriculum connections among state standards for science, mathematics, English language arts, and social studies.

Elaboration: There are multiple opportunities to integrate learning opportunities in science with other disciplines. For example, integrating text comprehension and writing strategies into science classrooms helps students to develop fluency with informational texts and build science knowledge (Varelas & Pappas, 2006; Vitale & Romance, 2007; Wallace, Hand, & Yang, 2004). Engaging students in developing and using models can provide opportunities for students to learn mathematical modeling and engage in computational thinking (Brady, Holbert, Soylu, Novak, & Wilensky, in press; Lehrer & Schauble, 2012; Wilensky, Brady, & Horn, 2014). Helping educators see and make these connections in their teaching can strengthen professional learning experiences and support implementation (Pearson, Moje, & Greenleaf, 2010).

PD leaders:	**Teachers:**
Structure opportunities for teachers to make connections between practices of disciplines, highlighting both similarities and differences Maintain integrity of three-dimensional learning when promoting connections across disciplines Provide teachers with opportunities to engage as learners in learning experiences that integrate other disciplines, such as writing strategies and text comprehension or mathematical modeling Provide teachers with opportunities to engage with videos and case studies of successful engagement of students in science learning that is integrated with other disciplines Provide teachers with a strategies for making connections to and integrating other disciplines in their curriculum	Reflect on different goals for learning in the disciplines Reflect on how to maintain integrity of learning goals of each discipline, when engaging in interdisciplinary teaching strategies Create or adapt, implement, reflect on, and revise teaching strategies and lesson plans that integrate other disciplines into science curriculum Engage students in practices from other disciplines to support science learning

Implementing and Sustaining a Professional Development Infrastructure

To implement and sustain effective professional learning opportunities, professional development providers should:

I1. Seek opportunities to enhance their own understanding of instructional strategies, curriculum materials, and educator learning experiences that embody the principles and vision of the *Framework for K-12 Education.* *Elaboration:* To develop an understanding of the major shifts being called for in science education, educators need opportunities to read, interpret, and make sense of the key ideas in the *Framework*. Such opportunities may occur during workshops, classes, or facilitated study groups in schools. Helping educators to understand the underlying principles of new policies and frameworks can support successful implementation (Fishman, Marx, Best, & Tal, 2003).	
PD leaders:	**Teachers:**
Take initiative to find new opportunities for learning about the *Framework* Recommend opportunities for teachers to add to their understanding of the *Framework* Select parts of the *Framework* to analyze with participants Structure opportunities to interpret significance of *Framework* text relevant to three-dimensional learning goals for teaching and learning Create formats for teachers to use in study groups in their schools	Take initiative to find new opportunities for learning about the *Framework* Analyze text related to all three dimensions of the *Framework* Analyze how well vision and principles of *Framework* are reflected in instructional materials Engage in study of the *Framework* in their professional learning groups in schools, both in grade level teams and across grade levels

I2. Develop long-term strategic plans to support educators' professional learning in collaboration with state, districts, schools, and educators themselves. *Elaboration:* Science educators must tailor professional learning opportunities to fit within the state, district, and educator contexts in which they are implemented. Such tailoring is important because educators' judgments about the coherence of professional development with larger policy goals shape what they do with what they learn in professional development (Penuel, Fishman, Gallagher, Korbak, & Lopez-Prado, 2009). Educator ownership is a critical component of bringing reforms to scale (Coburn, 2003; Datnow & Stringfield, 2000).	
PD leaders:	**Teachers:**
Become and stay aware of the changing goals and needs of teachers, schools, districts, and states they serve Recognize that PD should be adjusted to meet the needs of teachers, school, district and state Participate with teachers, leaders in schools, districts, and states in developing a coherent system of professional learning Involve teachers in designing and adapting designs of PD based on evidence of need and impact	Commit to long-term professional growth Participate in efforts at the school, district, and state level to define coherent systems of professional learning Work with providers to design, adapt, and co-lead designs for professional development Reflect on how well the state, district, school and their goals fit together

I3. Ensure that all educators have access to a variety of realistic, worthwhile, and extended learning experiences and the necessary instructional materials and equipment needed to implement the instructional approaches introduced during the professional learning experience.

Elaboration: At present, most educators experience only short-term workshops. Few educators have access to high-quality professional development that are of an extended duration (Banilower et al., 2013). Implementing instructional strategies introduced during professional development requires access to necessary materials. Educators without such access and knowledge of how to use materials effectively are unlikely to implement program elements, even if they are perceived to have potential value for students (Penuel, Shear, Korbak, & Sparrow, 2005).

PD leaders:	**Teachers:**
Provide incentives for retaining educators in long-term professional development opportunities that are well organized with clear goals for participants Develop and deliver well articulated programs that have long-term goals for improving instruction consistent with the state content standards for all teachers Locate instructional materials that are of high quality and that can be easily adapted to a 3D instructional approach Locate appropriate Open Educational Resources (OER) or other free resources for classroom use Create and/or utilize a template to guide teachers in selecting, developing, and adapting sequences of 3D lessons (e.g. EQuIP Rubric) Link educators to organizations (e.g., companies, nonprofits) looking to donate surplus to classrooms or looking to sponsor projects Access and share a list of grant opportunities	Use planning tools to organize and make professional development decisions that are consistent with an overall professional growth plan to improve science teaching skills Ask providers for evidence that their programs are aligned to the *Framework* and have positive impacts on teaching and learning Commit to and participate in long-term professional development central to improving teachers knowledge and skills for teaching science Evaluate, sample and pilot instructional materials Create an equipment needs list with potential vendors Advocate within school and district for needed materials Select companies or grants to pursue for funding as necessary

I4. Employ a variety of methods that promote educator collaboration within workshops, school-based teams, and in geographically dispersed networks.

Elaboration: Schools are important sites for educator learning, because educators may have the most frequent opportunities to learn from their colleagues. Professional learning opportunities that promote collective engagement have been linked to changes in educator beliefs and practice (Desimone et al., 2002). Technology can enable educators who are geographically dispersed to learn through digital collaboration (Fishman et al., 2013).

PD leaders:	**Teachers:**
Design PD that can be led within school-based teams	Share with colleagues and principal what they are doing in their PD
Design PD to be collaborative throughout and build relationships between teachers	Commit to collaborating after the PD with school-based or geographically dispersed teams
Promote use of technology to help teachers connect and collaborate after the PD	Form a team with colleagues in their school focused on inquiry into their classroom practice related to the PD
Share and model collaboration protocols and structures for teachers to use	Use collaboration protocols and structures within teams
Support teachers in making plans to engage colleagues in networks of professional learning	Seek out opportunities for participation in additional group learning opportunities (e.g., online, professional networks)

I5. Cultivate collegial trust and a sense of professional responsibility for program success within school-based educator teams and across individual participants in professional learning networks. *Elaboration:* Cultivating trust among colleagues and a sense that all educators share responsibility for student learning are key resources for reform at the school level. Successful collaborative learning among educators and leaders cultivates trust and a sense of collective responsibility for learning (Louis & Marks, 1998). Trust develops when groups of educators commit to and follow up on actions that improve student learning (Kochanek, 2005). Collective responsibility, the belief that educators' actions can make a difference in student learning, is the key to sustaining a commitment to continuous improvement (Bryk & Schneider, 2002; Lee & Smith, 1996).	
PD leaders:	**Teachers:**
Engage school leaders to develop understanding of PD goals, support participation in PD, and share how it helps school meet its goals Work with teachers to identify district and school leaders to whom they can turn for support and resources to improve teaching and learning in ways that align with PD goals Structure participation in activity to allow teachers from the same school and district to work together in professional development and make specific plans for implementation of new practices at their schools	Invite school and district leaders to take part in and support their participation in PD they value Identify resources (e.g., time, materials) they need to improve teaching and learning that leaders can provide Learn about their colleagues' strengths, challenges, and goals for improving their classroom teaching

I6. Develop readiness for educators to serve as mentors, resources, coaches, and leaders to sustain and support ongoing professional learning.

Elaboration: Bringing the vision of the *Framework* to scale depends on cultivating a large cadre of educator leaders, many of whom will serve as mentors and coaches to peers. Professional learning opportunities should prepare educators leaders for the demands of such roles, including cultivating trust and continually adjusting strategies to fit educators' changing circumstances and learning needs (Anderson, Feldman, & Minstrell, 2014).

PD leaders:	**Teachers:**
Design PD so that teachers, principals and instructional leaders are prepared to deliver similar professional learning experiences for others Provide a learning environment and follow-up communication system that links PD providers, teacher leaders, and teachers so they can consult each other informally as needed Use strategies to increase the sustainability of the professional development through providing participants with the tools to mentor others Provide clear message of the vision of the *Framework* and goals of science education and the professional learning experience Rehearse different coaching situations with teachers who present challenges to implementation in their school environment Design of professional development provides a clear way to transfer the learning to new situations (e.g., change in grade-level assignment, change to an administrative position, change to a formal coaching position.)	Engage in learning with the intent of becoming a mentor for others Engage in gathering and explicating instructional resources to both use in the classroom and share with others as model strategies and tools that are most effective Use collaborative protocols and structures from the professional learning experience to better prepare for mentoring others Use the instructional strategies and materials from the professional learning experiences with integrity for the purpose of analyzing the effectiveness of the materials in the classroom and sharing the findings with others Reflect on ways to improve the alignment of the professional learning experience to better meeting the needs of the audience you will be engaging or mentoring Synthesize and communicate a clear and cogent understanding of the vision of the *Framework* and the nature of instruction that engages student in science learning consistent with the goals of the *Framework*. Develop and reflect on knowledge of and practice with strategies for helping teachers find solutions to implementation challenges in their schools

Evaluating Professional Learning Opportunities

To evaluate professional learning opportunities, science educators should:

E1. Actively seek and apply contemporary research evidence about how students learn science and engineering. *Elaboration:* Educators must stay abreast of the growing body of evidence about how students learn science and the characteristics of successful professional development. The most effective strategies for supporting research acquisition use among practitioners is to cultivate sustained interactions with research and researchers (National Research Council, 2012).	
PD leaders:	**Teachers:**
Recognize that research knowledge accumulates through multiple studies, and that a single finding should be understood in a wider body of knowledge Translate findings from research into PD designs and applications for the classroom Locate and reference other programs and opportunities that support the PD and also allow teachers to continue learning outside of PD Partner with researchers to learn more about student science learning and to support creation of professional development Engage in a community of science professional learning to stay abreast of growing evidence of how students learn science	Review, discuss, and use resources that synthesize research findings created by researchers and other teachers to deepen an understanding of how students learn science Engage in research that supports learning in the classroom Transition from old methods to new methods of instruction in light of new research and evidence Reflect on how perceptions of (teacher and) student learning of science has changed over time Ask questions about claims made in professional development

E2. Use evidence from student assessments to modify or adjust components of professional learning programs. *Elaboration:* Evidence about professional learning opportunities needs to include more than questionnaires presented to educators about their opinions of workshops and other experiences. It should also include evidence related to how students benefit when educators participate in professional learning opportunities. Modifying program components based on student assessment data can improve science learning (Fishman et al., 2003).	
PD leaders:	**Teachers:**
Plan for collecting or obtaining data on student learning outcomes Establish trend lines over years of student pre and post assessment data for participants involved in PD vs comparable groups not involved in PD Plan for reflection in which they examine data on student assessments to identify PD strategies that have the highest impact on student assessments and what might explain why these are effective Adjust PD to reflect strategies that have greatest impact on PD	Collect pre- and post- assessments and submit for common scoring or facilitate access to district data on their students

E3. Capture ideas, perspectives, and formative and summative data from all participants to evaluate program elements and outcomes.

Elaboration: Beyond student assessment data, science educators need to document breadth of who attends professional development, including roles of teachers in their organizations, engagement of teachers in PD, evidence related to the implementation and perceived effectiveness of various components of professional development, and impacts on teachers' beliefs, knowledge, and instruction. Documentation is important because educators who might benefit most from professional development do not always receive it (Desimone, Smith, & Ueno, 2006), and professional development components are not always implemented as intended.

PD leaders:	**Teachers:**
Plan evaluation of PD ahead of time by identifying the program's theory of action: key program elements, activities, and outcomes Gather data on characteristics, organizations, and roles of participants in the PD Capture data on the PD as implemented, using observation protocols and or surveys and then comparing against PD agendas Gather and make use of data from teachers after the PD on their testing of strategies in classrooms and the impact of the PD on teachers beliefs, knowledge, and instruction (both in the short-term and long-term) Seek input from school and district leaders on impact of PD and what might make it more effective	Respond to reasonable requests for follow-up data from PD providers Request evaluation data/findings on the PD they attend

E4. Use data about outcomes and financial decisions to make programs more cost-effective.

Elaboration: Costs of professional learning programs can vary widely (Odden, Archibald, Fermanich, & Gallagher, 2002). Some programs that are effective may cost less than others (e.g., Shear & Penuel, 2010). Therefore, it is necessary for science educators to use data on outcomes and expenses to make professional learning opportunities more cost-effective.

PD leaders:	**Teachers:**
Identify cost and payment requirements for teachers in participating districts Document costs of professional development, including space, time, and materials Compare costs to benefits documented from evaluation and analyze changes to costs and benefits over time Include incentives for teachers to use the instructional strategies and materials from the professional learning standards for themselves and share with others	Report to PD providers time spent outside of PD related to it, both compensated and uncompensated Report to PD providers any purchases or hidden costs to participation (e.g., mileage, child care)

E5. Assess the degree to which participants are treated with respect as professional educators during each aspect of professional development.

Elaboration: Professional development should expand educators' agency within the process of change. By preparing educators to productively adapt instructional strategies and materials rather than simply to implement them with fidelity, professional development can help educators feel ownership over reform and feel respected by professional development providers (DeBarger, Choppin, Beauvineau, & Moorthy, 2013).

PD leaders:	**Teachers:**
Conduct surveys of teachers' experiences of PD, particularly the degree to which PD leaders showed respect, helped them make connections to other teachers, developed buy-in to *Framework* Assess perceived value to educators during the PD and make adjustments to the PD based on teachers' experiences	Share openly and professionally when the PD is and is not meeting their needs with the PD leaders

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