Executive Summary

Teacher professional learning is of increasing interest as one way to support the increasingly complex skills students need to learn in preparation for further education and work in the 21st century. Sophisticated forms of teaching are needed to develop student competencies such as deep mastery of challenging content, critical thinking, complex problem-solving, effective communication and collaboration, and self-direction. In turn, effective professional development (PD) is needed to help teachers learn and refine the pedagogies required to teach these skills.

However, research has shown that many PD initiatives appear ineffective in supporting changes in teacher practices and student learning. Accordingly, we set out to discover the features of effective PD. This paper reviews 35 methodologically rigorous studies that have demonstrated a positive link between teacher professional development, teaching practices, and student outcomes. We identify the features of these approaches and offer rich descriptions of these models to inform those seeking to understand the nature of the initiatives.

Defining and Studying Effective Professional Development

We define effective professional development as structured professional learning that results in changes in teacher practices and improvements in student learning outcomes. To define features of effective PD, we reviewed studies meeting our methodological criteria (see Appendix A) that emerged from our extensive search of the literature over the last three decades. We coded each of the studies to identify the elements of effective PD models.

Using this methodology, we found seven widely shared features of effective professional development. Such professional development:

Is content focused: PD that focuses on teaching strategies associated with specific curriculum content supports teacher learning within teachers' classroom contexts. This element includes an intentional focus on discipline-specific curriculum development and pedagogies in areas such as mathematics, science, or literacy.

Incorporates active learning: Active learning engages teachers directly in designing and trying out teaching strategies, providing them an opportunity to engage in the same style of learning they are designing for their students. Such PD uses authentic artifacts, interactive activities, and other strategies to provide deeply embedded, highly contextualized professional learning. This approach moves away from traditional learning models and environments that are lecture based and have no direct connection to teachers' classrooms and students.

Supports collaboration: High-quality PD creates space for teachers to share ideas and collaborate in their learning, often in job-embedded contexts. By working collaboratively, teachers can create communities that positively change the culture and instruction of their entire grade level, department, school and/or district.

Uses models of effective practice: Curricular models and modeling of instruction provide teachers with a clear vision of what best practices look like. Teachers may view models that include lesson plans, unit plans, sample student work, observations of peer teachers, and video or written cases of teaching.

Provides coaching and expert support: Coaching and expert support involve the sharing of expertise about content and evidence-based practices, focused directly on teachers' individual needs.

Offers feedback and reflection: High-quality professional learning frequently provides built-in time for teachers to think about, receive input on, and make changes to their practice by facilitating reflection and soliciting feedback. Feedback and reflection both help teachers to thoughtfully move toward the expert visions of practice.

Is of sustained duration: Effective PD provides teachers with adequate time to learn, practice, implement, and reflect upon new strategies that facilitate changes in their practice.

Our research shows that effective professional learning incorporates most or all of these elements. We also examine professional learning communities (PLCs) as an example of a PD model that incorporates several of these effective elements and supports student learning gains. This collaborative and job-embedded PD can be a source of efficacy and confidence for teachers, and can result in widespread improvement within and beyond the school level.

Creating Conditions for Effective Professional Development: Opportunities and Challenges

Research has established that the educational system within which PD occurs has implications for its effectiveness. Specifically, conditions for teaching and learning both within schools and at the broader, system level can inhibit the effectiveness of PD. For example, inadequate resourcing for PD—including needed curriculum materials—frequently exacerbates inequities and hinders school improvement efforts. Failure to align policies toward a coherent set of practices is also a major impediment, as is a dysfunctional school culture. Implementing effective PD well also requires responsiveness to the needs of educators and learners and to the contexts in which teaching and learning will take place.

Implications for Policy and Practice

Examples of PD that have been successful in raising student achievement can help policymakers and practitioners better understand what quality teacher professional learning looks like. Policy can help support and incentivize the kind of evidence-based PD described here. For instance:

1. Policymakers could **adopt standards for professional development** to guide the design, evaluation, and funding of professional learning provided to educators. These standards might reflect the features of effective professional learning outlined in this report as well as standards for implementation.

2. Policymakers and administrators could **evaluate and redesign the use of time and school schedules** to increase opportunities for professional learning and collaboration, including participation in professional learning communities, peer coaching and observations across classrooms, and collaborative planning.

3. States, districts, and schools could regularly **conduct needs assessments** using data from staff surveys to identify areas of professional learning most needed and desired

by educators. Data from these sources can help ensure that professional learning is not disconnected from practice and supports the areas of knowledge and skills educators want to develop.

4. State and district administrators could **identify and develop expert teachers as mentors and coaches** to support learning in their particular area(s) of expertise for other educators.
5. States and districts can **integrate professional learning into the Every Student Succeeds Act (ESSA) school improvement initiatives**, such as efforts to implement new learning standards, use student data to inform instruction, improve student literacy, increase student access to advanced coursework, and create a positive and inclusive learning environment.
6. States and districts can **provide technology-facilitated opportunities for professional learning and coaching**, using funding available under Titles II and IV of ESSA to address the needs of rural communities and provide opportunities for intradistrict and intraschool collaboration.
7. Policymakers can **provide flexible funding and continuing education units** for learning opportunities that include sustained engagement in collaboration, mentoring, and coaching, as well as institutes, workshops, and seminars.

In the end, well-designed and implemented PD should be considered a essential component of a comprehensive system of teaching and learning that supports students to develop the knowledge, skills, and competencies they need to thrive in the 21st century. To ensure a coherent system that supports teachers across the entire professional continuum, professional learning should link to their experiences in preparation and induction, as well as to teaching standards and evaluation. It should also bridge to leadership opportunities to ensure a comprehensive system focused on the growth and development of teachers.

Another crucial element is the knowledge that teachers bring to the PD experience—and whether it is sufficient to support their learning of particular pedagogical strategies. In one interesting case, where mathematics PD was conducted in a district that had very large numbers of uncredentialed teachers, researchers found positive effects on student learning only for those teachers who began with a higher level of content knowledge, signaling that the effectiveness of PD may depend in part on how solid a content foundation teachers have with which to absorb its lessons.[13] These and other considerations may influence the effectiveness of PD, even when it may share some of the features we identify here. Although it is beyond the scope of this paper to unpack why specific initiatives have proved less than fully successful, we identify barriers to the implementation of effective PD as identified by researchers later in this paper.

> We aim to provide a research-based understanding of the kinds of PD that can lead to powerful professional learning, instructional improvement, and deeper student learning.

Goals and Outline of This Report

Our primary goal is to illuminate the features of PD that have been found to be effective, in hopes that this analysis can help inform policymakers and practitioners responsible for designing, planning, and implementing potentially productive opportunities for teacher learning.

We aim to provide practitioners, researchers, and policymakers with a research-based understanding of the kinds of PD that can lead to powerful professional learning, instructional improvement, and deeper student learning. By examining information about the nature of effective PD, policymakers and practitioners can begin to evaluate the needs of the systems in which teachers learn and do their work and consider how teachers' learning opportunities can be more effectively supported.

In the sections that follow, we first review the elements of effective PD initiatives identified through our review of recent literature, offering examples from specific studies and PD models. We then explore how the currently popular phenomenon of professional learning communities—often superficially implemented—can be effectively organized. Next, we provide an overview of the broader conditions that support or inhibit effective teacher PD in the United States, drawing on the broader PD literature. We conclude with considerations for policy and practice.

Thirty-one of the 35 studies we reviewed featured a specific content focus as part of the PD model. Among the PD models without a specific content focus, two focused on specific pedagogies that were not discipline specific,[29] and one study focused on supporting teachers in promoting inquiry-based learning and leveraging technology in support of standards-based instruction.[30] A final study provided insufficient description of the PD to determine whether or not the PD was content specific.[31]

> Ideally, the PD is aligned with school and district priorities, providing a coherence for teachers, as opposed to having PD compete with differing school and district priorities.

One study of PD for upper elementary teachers, which focused on helping teachers analyze science teaching and improve pedagogy, illustrates job-embedded and content-focused PD. Roth et al. (2011) studied teachers participating in The Science Teachers Learning from Lesson Analysis (STeLLA) program.[32] The project focused on both science content and pedagogy using a video-based analysis-of-teaching PD model. The PD began with a three-week summer institute focused on science content taught by faculty at a local university. Teachers in the STeLLA program also engaged in video analysis of teaching during the summer institute. In follow-up sessions throughout the school year, teachers utilized Student Thinking and Science Content Storyline Lenses, creating PD that was both content specific and classroom based. The Student Thinking portion of the PD focused on understanding students' ideas for use in planning, teaching, and analysis of teaching—particularly in anticipating student thinking to assist teachers in responding to students' ideas and misunderstandings in productive ways. The Science Content Storyline portion of the PD focused on the sequencing of science ideas and how they are linked to help students construct a coherent "story" that makes sense to them. STeLLA teachers met in small groups facilitated by a program leader and discussed video cases of teaching that could include video(s) of one classroom, student and teacher interviews, teacher materials, and student work samples.[33]

STeLLA teachers also taught a set of four to six model lessons themselves and analyzed their teaching using a structured protocol. Half of a study group would teach the lessons to their students, and the entire group would collaboratively analyze the teaching and student work, and revise the lessons for the other half to use. The roles would then switch and the second half of the group would teach the lessons in their classrooms, followed by collaborative analysis and subsequent revision. The analysis was highly scaffolded by the PD facilitators. STeLLA groups met for 58 hours of analysis throughout the school year, in addition to 44 hours during the three-week summer session for a total of 102 hours. Roth et al. (2011) studied this group of teachers in comparison to a group of teachers who only attended the science content portion of the PD program.[34] The content-only teachers received just the 44 hours of PD, and it was not explicitly connected to their classroom contexts.

Results of the study showed that teachers who participated in the STeLLA program had students who achieved greater learning gains than comparison students whose teachers received content training only, as determined by pre- and post-test science content exams. Statistical analyses linked these gains in student learning with teachers' science content knowledge, teachers' pedagogical content knowledge about student thinking, and teachers' ability to create a cohesive science content storyline. STeLLA teachers outperformed the content-only teachers and, moreover, were able to retain their content learning whereas content-only teachers were not.[35] A second randomized study of the STeLLA program similarly found positive effects for students of participating teachers.[36] This study, similar to other studies in this review, suggests that PD that treats only content learning is not as effective as PD that links content learning to pedagogies supporting teachers' students and practice.[37]

Teacher professional learning that is context specific, job embedded, and content based is particularly important for addressing the diverse needs of students (and thus teachers) in differing settings. For example, in one study of PD for elementary science teachers in an urban school district, teachers of Latinx students learned science content as well as conversational Spanish and strategies for using culturally relevant pedagogies.[38] In another program targeting teachers of Latinx dual-language learners, monolingual teachers were provided with a range of instructional strategies to support children's primary language development in Spanish.[39] The key features of focusing on students' culture and language in these content- and context-specific PD models illustrate teacher professional learning opportunities designed for teaching content to specific student populations with targeted strategies to support their achievement.

Adults come to learning with experiences that should be utilized as resources for new learning.

Active Learning

The design of PD experiences must address *how* teachers learn, as well as *what* teachers learn. Trotter (2006) outlines several theories of learning and adult development and identifies themes that are relevant for designing teacher PD.

- Adults come to learning with experiences that should be utilized as resources for new learning.
- Adults should choose their learning opportunities based on interest and their own classroom experiences/needs.
- Reflection and inquiry should be central to learning and development.[40]

These themes provide a general framing that helps to explain why teacher PD that incorporates active learning experiences is effective in supporting student learning and growth. "Active learning" suggests moving away from traditional learning models that are generic and lecture based toward models that engage teachers directly in the practices they are learning and, preferably, are connected to teachers' classrooms and students. Active learning, in sharp contrast to sit-and-listen lectures, engages educators using authentic artifacts, interactive activities, and other strategies to provide deeply embedded, highly contextualized professional learning. Active learning is also an "umbrella" element that often incorporates the elements of collaboration, coaching, feedback, and reflection and the use of models and modeling.

Opportunities for "sense-making" activities are important.[41] Such activities often involve modeling the sought-after practices and constructing opportunities for teachers to analyze, try out, and reflect on the new strategies.[42] Active learning opportunities allow teachers to transform their teaching and not simply layer new strategies on top of the old, a hallmark of adult learning theory.[43]

Greenleaf et al. (2011) describe an active teacher professional learning model that improved student science learning.[44] California high school biology teachers participated in PD integrating academic literacy and biology instruction through a program called Reading Apprenticeship. The PD was inquiry based, subject focused, collaborative, and designed to address teachers' conceptual understandings as well as pedagogical content knowledge. Each session was designed to immerse the teachers in the types of learning activities and environments they would then create for their students. Teachers engaged in activities to simulate their own discipline expertise in relation to literacy, and they also engaged in analysis of texts to identify potential literacy challenges to learners.[45]

In addition, teachers analyzed student work, videotaped classroom lessons, and studied cases of student literacy learning designed to foster high expectations of student learning. Metacognitive routines such as think-alouds and reading logs for science investigations were used in PD sessions. Teachers also practiced classroom routines to build student engagement and student collaboration (e.g., "think-pair-share," jigsaws, text-based student discussion, and problem solving). An important part of the PD was a metacognitive reflection after each session that focused on the session's impact on teachers' learning and potential impact on their students' development.[46]

The program employed 10 sessions over the course of a year. An initial five-day institute took place the first summer of the study, followed by two follow-up days of PD during year 1 and a final three-day PD follow-up the summer after the academic year. During the study year, participants engaged in collaboration on a listserv that fostered the exchange of resources and ideas and was moderated by PD coaches. This multimodal, active learning PD model resulted in student achievement equivalent to a year's reading growth compared with students of teachers assigned to a control group. Students of treatment teachers also performed better than their counterparts in control classrooms on state assessments in English language arts and biology.[47]

The opportunity for teachers to engage in the same learning activities they are designing for their students is often utilized as a form of active learning. Several studies in this review highlighted PD programs that had teachers engage as learners through the use of curriculum and materials that they would then employ with their students. For instance, Buczynski and Hansen (2010) describe how 4th through 6th grade teachers had the opportunity to participate in "constructivist, hands-on experiences" through the use of science kits.[48] These were the same science kits that teachers would then go on to use in their classrooms with their students. Similarly, teachers in a study by Heller et al. (2012) completed the same scientific investigations they analyzed in written teaching cases.[49] In other studies, pedagogical and content experts would "teach" model lessons with teachers engaging as learners.[50] Additionally, two studies incorporated role-playing as a part of teachers "practicing" lessons with their peers to better understand students and their learning.[51]

The opportunity for teachers to engage in the same learning activities they are designing for their students is often utilized as a form of active learning.

Overall, 34 of the 35 studies incorporated some element of active learning in the design of the PD, while one study did not provide enough description of the PD model to ascertain whether active learning was present.

Collaboration

As schools have increasingly structured teaching as a collaborative community endeavor, it makes sense that teacher collaboration is an important feature of well-designed PD.[52] "Collaboration" can span a host of configurations—from one-on-one or small-group interactions to schoolwide collaboration to exchanges with other professionals beyond the school.

As schools have increasingly structured teaching as a collaborative community endeavor, it makes sense that teacher collaboration is an important feature of well-designed PD.

In a program studied by Allen et al. (2011), teachers collaborated with a one-on-one coach.[53] In this study, Virginia high school teachers enrolled in My Teaching Partner-Secondary, a web-mediated coaching program designed to improve teacher-student interactions. Teachers participated in an initial training workshop followed by twice-monthly coaching from a remote mentor. For each coaching session, teachers were asked to submit short videos of their practice, reflect on their teaching, and respond to questions from their coach regarding the relationship between teacher practice and student engagement. Each reflection was followed by a 20- to 30-minute phone conference with the coach. Teachers also attended monthly booster workshops and were given access to an annotated video library for the duration of the program.[54]

Overall, the program offered 20 hours of in-service training over 13 months, in addition to the focused work teachers were doing in their classrooms to design and reflect on their practice. Students whose teachers had participated in the program the previous school year demonstrated gains in student achievement relative to the control group, with student learning gains equivalent to an average increase from the 50th to 59th percentile.[55] A replication study featuring an extended, two-year version of the My Teaching Partner-Secondary model found similar promising results.[56] This model of PD is especially promising for teachers who may be in remote or rural schools and may not have access to professional learning opportunities more readily available in suburban or urban areas.

Other studies have looked at collaboration at the school level.[57] One New Zealand study focused on schoolwide PD efforts in 195 schools spread across four cohorts of teachers.[58] Teachers in these schools participated in a flexible whole-school professional development model designed to improve student literacy, particularly for low-performing students. Each of the participating schools selected a focus on reading or writing for the duration of the two-year project and was assigned an expert literacy facilitator to provide PD for teachers and school leaders.

Facilitators visited each school biweekly to conduct classroom observations, model literacy instruction, provide coaching and feedback, and engage in discussion and other activities with school staff. Facilitators also trained a literacy leader at each school who provided additional support for colleagues. The project provided resources such as classroom observation and facilitation tools, as well as training and feedback for the expert facilitators throughout the two years. Students attending schools participating in the project outperformed achievement expectations relative to a nationally normed sample, especially in writing. Students in schools with a focus on improving writing improved at 2.9 to 3.5 times the expected rate. Students in schools with a focus on improving reading improved at 1.4 to 1.6 times the expected rate.[59]

Such collaborative approaches have been found to be effective in promoting school change that extends beyond individual classrooms.[60] When whole grade levels, departments, or schools are involved, they provide a broader base of understanding and support at the school level. Teachers create a collective force for improved instruction and serve as support groups for each other's work on their practice. Collective work in trusting environments provides a basis for inquiry and reflection into teachers' own practices, allowing teachers to take risks, solve problems, and attend to dilemmas in their practice.[61]

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Other studies focused on districtwide collaborative PD in efforts to bring larger-scale improvements to teaching and learning.[62] For example, in one Texas district, teachers engaged in on-site, small-group PD to promote inquiry-based, literacy-integrated instruction to improve English learners' science and reading achievement.[63] Through the program, teachers and paraprofessionals participated in workshops where they reviewed upcoming lessons, discussed science concepts with peers, engaged in reflections on student learning, participated in inquiry activities as learners, and received instruction in strategies for teaching English learners. Researchers also provided teachers with lesson plans that incorporated strategies for effective instruction of English learners. Teachers met biweekly for collaborative, three-hour sessions, receiving six hours of PD per month; paraprofessionals met monthly for three hours. The program also included a focus on new and enhanced instructional activities for English learners.

Students who received enhanced instructional activities and whose teachers received PD demonstrated significantly higher science and reading achievement than students who were engaged in business-as-usual instruction. Treatment students also earned passing and commended scores on district science benchmarks at higher rates than control group students.[64] By focusing on improving the practice of teachers of English language learners, this kind of collaborative, districtwide PD can have important implications for improving the equity of whole systems.

Technology-facilitated PD such as the web-mediated coaching program studied by Allen et al. (2011) can also foster cyber collaboration,[65] which can be effective in improving student achievement.[66] Landry et al. (2009), for example, describe a well-designed online PD program that improved early literacy outcomes for young children.[67] In that study, described in additional detail later in the Feedback and Reflection section*,* early childhood educators participated in a facilitated online course on language and literacy instruction. The interactive course included videos models, message boards, and opportunities to practice skills in small groups. In this case, technology facilitated the incorporation of collaboration and other effective PD elements, such as active learning and modeling, in the professional learning design.

Overall, 32 of 35 studies we reviewed incorporated some element of collaboration to support teacher professional learning, while three studies did not provide sufficient description to determine whether or not collaboration was a part of the model design. When PD utilizes effective collaborative structures for teachers to problem-solve and learn together, it can positively contribute to student achievement.

Use of Models and Modeling

PD that utilizes models of effective practice has proven successful at promoting teacher learning and supporting student achievement. Curricular and instructional models and modeling of instruction help teachers to have a vision of practice on which to anchor their own learning and growth. The various kinds of modeling can include

- video or written cases of teaching,
- demonstration lessons,
- unit or lesson plans,
- observations of peers, and
- curriculum materials including sample assessments and student work samples.

All 35 studies reviewed here included curricular models and/or modeling of effective instruction in the delivery of content and pedagogical learning for teachers. For example, Heller et al. (2012) conducted a randomized experimental design of three intervention groups and one control group to study the effects of PD on elementary students' learning in science.[68] The PD focused on pedagogical science content knowledge for elementary teachers, utilizing three different interventions, all of which proved successful in improving student achievement.

> Curricular and instructional models and modeling of instruction help teachers to have a vision of practice on which to anchor their own learning and growth.

One group of teachers analyzed written teaching cases, drawn from actual classrooms and written by teachers. Thus, the PD was an "analysis of practice" approach that incorporated models for student work analysis, student teacher dialogue analysis, and teacher thinking and behaviors. A second group analyzed their own students' work in relation to their teaching. Teachers in this intervention experienced carefully structured, collaborative analysis of their own students' work, which required that they teach a unit. Discussion protocols for the analysis of student work were employed that focused teachers' analysis on student understanding of content. These teachers took turns bringing in student work samples and formative assessment tasks that they analyzed collaboratively. Teachers also had access to a "task bank" of formative assessment model items they could use with their students. A third group utilized metacognitive analysis of their own learning experience in the form of reflective discussions about their own learning processes as they engaged in science content activities.

The course was designed to help teachers identify concepts they found challenging to learn, examine the logic behind their own common misunderstandings of the content, and analyze the roles of hands-on investigations, discourse, and inquiry in science learning. Expert staff developers delivered a series of three courses (the PD was delivered in 8 three-hour sessions, for a total of 24 contact hours with a facilitator).[69]

Findings of this study showed that students of teachers who participated in any of the PD opportunities had significantly greater learning gains on science tests than students whose teachers did not participate (with average gains of 19-22 percentage points compared to 13 points for control students). These effects were maintained a year later. Student justification of correct answers in year 1 of the study showed significant improvement from pre- to post-test for those students whose teachers analyzed student work samples (which incorporated the use of model assessments, as noted above). In the follow-up year, teachers who utilized cases of teaching also had significantly higher answer justification scores. Those teachers who focused on metacognitive analysis of their own learning experience showed no student gains in written justification of correct answers. The findings of this study are notable because the strongest effects on written justifications of answers, a task more complex than identifying correct answers on a content exam, are connected to the PD that focused on models of effective practice, including curricula and instruction, in combination with student work analysis and classroom pedagogical practice.[70]

The importance of providing professional learning in conjunction with model curriculum and classroom materials should not be underestimated. Several studies in this review compared groups of teachers who had access to curriculum with no support to those teachers who received curriculum with additional support. For example, Kleickmann et al. (2016) found that teachers who utilized educational curriculum materials alone had lower student achievement than those teachers who had access to those materials *and* expert support combined with collaborative active learning opportunities that focused heavily on sequencing and presenting science concepts to facilitate student learning.[71]

The importance of providing professional learning in conjunction with model curriculum and classroom materials should not be underestimated.

Doppelt et al. (2009) reported similar findings.[72] Teachers in this study participated in content-based collaborative inquiry sessions as support for a new 8th-grade science curriculum focused on electronics. Teachers participated in active learning based on the new curriculum—they engaged in the model lessons just as their students would. In addition, they spent much time in the workshops reflecting on instructional activities in their classrooms. They shared student work and instructional materials, actively discussing and reflecting on instruction. Students whose teachers used the new curriculum and participated in PD had statistically greater achievement than those students whose teachers used the new curriculum with no PD. Even more significant, achievement for students of those teachers who continued to use the older standard curriculum was greater than that of those students whose teachers used the new curriculum with no PD.[73] That suggests that students were better off if their teachers did not attempt to utilize new curricular materials without effective PD supporting them.

Coaching and Expert Support

The previous sections foreshadowed the role experts can have in helping to guide and facilitate teachers' learning in the context of their practice. In their work with educators, experts—typically educators themselves—often play this critical role by employing the types of professional learning strategies outlined above, such as modeling strong instructional practices or supporting group discussion and collaborative analysis of student work. Such coaches may also share expertise about content and evidence-based practices, as well.

The practice of providing coaching or other expert support for educators was identified in 30 of the 35 studies reviewed. Four of the studies did not specify who delivered the PD or whether expert support was offered. In one case, coaching and expert support were not offered as part of the PD:

Shaha and Ellsworth (2013) describe a web-based PD platform with opportunities for teachers to engage with PD content through objective-setting, videos, forums, and communities, without specified expert support.[74]

One common structure for providing expert support is one-on-one coaching in the context of a teacher's own classroom.[75] Experts also shared their knowledge as facilitators of group workshops[76] or as remote mentors utilizing technology to communicate with educators.[77] Individuals with a variety of backgrounds can fill the role of expert; in the reviewed studies, coaches and other experts ranged from specially trained master teachers[78] and instructional leaders[79] to researchers and university faculty.[81] For example, Roth et al. (2011) relied on both program leaders to facilitate small-group learning and university-based scientists to teach science content to educators.[81]

The coaching model studied by Powell and colleagues (2010) offers an example of expert support that contributed to student learning gains.[82] The PD was designed to provide early childhood educators with individualized feedback to improve early literacy instruction. Educators attended an initial two-day orientation that introduced program content and fostered relationship building between coaches and educators. Educators then participated in biweekly coaching sessions with a university-based literacy coach, in person or remotely.

Across both formats, coaches and teachers worked together to choose a specific instructional practice on which to focus each session. Coaches then observed the teachers' practice and provided both supportive and constructive feedback. On-site coaches observed educators for approximately 90 minutes, then the two met for 30 minutes to debrief the observation and provide oral and written feedback, including recommendations to improve practice. For remote coaching, educators shared 15-minute video clips and coaches provided detailed written feedback, supported by links to video exemplars and other materials available through the program. The semester-long program included 16 hours of workshops and seven coaching sessions.[83]

A two-year randomized control trial found that classrooms led by educators who participated in this coaching model demonstrated larger gains and higher performance on a valid and widely used early childhood classroom quality assessment than did control group classrooms. Children whose teachers participated in the early literacy coaching program showed significantly larger gains and better performance on a number of early language and literacy skills than did those whose teachers had not participated.[84]

Coaching or other expert scaffolding can support the effective implementation of new curricula, tools, and approaches by educators.

Recent literature also suggests that coaching or other expert scaffolding can support the effective implementation of new curricula, tools, and approaches by educators.[85] This is consistent with earlier research providing evidence that teachers who receive coaching are more likely to enact desired teaching practices and apply them more appropriately than those receiving more traditional PD.[86] Taken together, the literature demonstrates that expert supporters can play a critical role in creating effective PD.

Feedback and Reflection

Feedback and reflection are two other powerful tools found in effective PD; they are often employed during mentoring and coaching but are not limited to these spaces. As noted earlier, feedback and reflection are critical components of adult learning theory. Professional development models associated with gains in student learning frequently provide built-in time for teachers to think about, receive input on, and make changes to their practice by providing intentional time for feedback and/or reflection. While feedback and reflection are two distinct practices, they work together to help teachers move thoughtfully toward the expert visions of practice that they may have learned about or seen modeled during PD.

> Professional development models associated with gains in student learning frequently provide built-in time for teachers to think about, receive input on, and make changes to their practice.

Thirty-four of the 35 reviewed studies specified that PD included efforts to support educators in reflecting on their practice; one study offered no data about reflections on practice. Greenleaf and colleagues (2011) documented one approach to incorporating reflection into PD models.[87] After high school biology teachers participated in literacy activities as learners, they participated in a debrief, describing the elements of the activity that extended their literacy learning and considering implications and adaptations of the pedagogy for their classrooms. This reflection process was designed to bolster teachers' own learning and to support their teaching literacy in science.

In addition, 24 studies outlined processes for providing educators with feedback on their practice. (The remaining 11 did not specify whether feedback was provided to participants). Landry and colleagues (2009) describe multiple opportunities for educators to receive feedback in a program targeting early childhood educators' ability to promote children's language and literacy development.[88] In the program, which was implemented across four states, educators enrolled in a facilitated online course focused on language and literacy instruction, eCIRCLE. The course included videos of model lessons, online coursework and knowledge assessments, and opportunities to plan lessons and practice skills in small groups and in teachers' own classrooms. The course also offered interactive message boards that were moderated by expert facilitators. Teachers participated in four hours of this coursework per month throughout the school year. Participating educators also received a supplemental curriculum on preschool language and literacy skills and were encouraged to monitor children's language and literacy progress using a standardized tool. In addition, some educators participated in biweekly onsite mentoring sessions with the expert facilitators. For those educators receiving mentoring, mentors first observed teacher practice, then facilitated reflective follow-up and provided both positive and constructive feedback to educators using a structured format. Whether through online forums or in-person coaching, teachers participating in the program were offered opportunities to receive feedback from specially trained experts.[89]

The researchers' randomized controlled study of the program found that students of teachers who received PD through the program demonstrated greater gains in phonological awareness, an important emergent literacy skill, than students of those who did not.[90] Researchers also found that students of teachers who received both expert mentoring and feedback on children's progress experienced the greatest gains on a variety of language and literacy outcomes.

In effective PD programs, the practices of generating feedback and supporting reflection often include opportunities to share both positive and constructive reactions to authentic instances of teacher practice, such as lesson plans, demonstration lessons, or videos of instruction.[91] These activities are frequently undertaken in the context of a coaching session[92] or a group workshop facilitated by an expert.[93] In a few cases, feedback was shared among teachers.[94] In each of these settings, effective PD programs leveraged feedback and opportunities for reflection to create richer environments for teacher learning.

Sustained Duration

Providing PD that exhibits the aforementioned characteristics and results in meaningful professional learning requires time and quality implementation. Though research has not yet identified a clear threshold for the duration of effective PD models, it does indicate that meaningful professional learning that translates to changes in practice cannot be accomplished in short, one-off workshops.[95] The traditional episodic and fragmented approach to PD does not afford the time necessary for learning that is "rigorous" and "cumulative."[96] Professional development that is sustained, offering multiple opportunities for teachers to engage in learning around a single set of concepts or practices, has a greater chance of transforming teaching practices and student learning.

> The traditional episodic and fragmented approach to PD does not afford the time necessary for learning that is rigorous and cumulative.

None of the PD initiatives described in this review occurred in the context of a single, isolated encounter.[97] The programs instead typically spanned weeks, months, or even academic years, with ongoing engagement in learning by teachers. These findings are consistent with previous literature on the duration of effective PD, which suggests that professional learning must be sustained to have an impact.[98] Beyond the findings of many studies of individual PD programs, Wenglinsky (2000) found in an analysis of National Assessment of Educational Progress (NAEP) data that spanned many different teacher experiences across the country that stronger instructional practices in mathematics and science were associated with professional development that was extended and sustained.[99] In a review of literature, Yoon et al. (2007) identified nine studies of PD using experimental or quasi-experimental designs and found that the effective PD models examined in these studies offered an average of 49 hours of development per year, with an associated average boost in student achievement of 21 percentile points.[100]

Thirty-one of the 35 studies we reviewed explicitly described PD that was sustained over time through recurring workshops, coaching sessions, or engagement with online platforms; the remaining four studies did not specify a particular format or duration. The most common model for PD among these studies was participation in an initial, intensive workshop, followed by applications in the classroom and additional development days or coaching sessions to extend and reinforce educator learning.[101] For example, teachers participating in the middle school science PD program described by Penuel et al. (2011) attended a two-week summer workshop, followed by ongoing work in their classrooms supported by four development days throughout the school year.[102] Several other studies engaged teachers in formal coursework that followed a traditional academic schedule.[103]

Another common strategy is to engage teachers in multiple sessions of a similar structure, often over a semester or school year, to promote meaningful professional learning.[104] The program described by Heller et al. (2012) included 8 three-hour sessions in which certain ideas about science instruction were taught and discussed, while teachers also engaged in related activities in their classrooms between the sessions. The model studied by Doppelt et al. (2009) was delivered in five workshops, each lasting four hours.[105] Between workshop classes, the teachers implemented related activities, which were grist for their reflections and discussion in the workshops. Although these models varied in the overall duration of the PD and the distribution of hours across the program, all provided opportunities for learning across multiple engagements, along with the ongoing connected learning that occurred for teachers within their classrooms as they applied the curriculum ideas and teaching strategies they were working on in the course or workshop series.

One benefit of sustained PD may be the opportunity for teachers to continue their learning outside the formal meetings of the program, whether in their own classroom, in collaboration with colleagues, or by less formal means. As Darling-Hammond et al. (2009) argue: "The duration of professional development appears to be associated with stronger impact on teachers and student learning—in part, perhaps, because such sustained efforts typically include applications to practice, often supported by study groups and/or coaching."[106] By returning to PD settings over time, teachers have an opportunity to refine and apply their understanding of material in their classrooms.

For example, the two-year PD model studied by Johnson and Fargo (2014) engaged teachers in intensive summer workshops as well as ongoing learning during the school year to enhance science instruction for Spanish-speaking elementary school students.[107] The program began with a two-week summer workshop that included graduate-level coursework on teaching elementary science, as well as an orientation to a new, inquiry-based science curriculum and strategies for culturally relevant pedagogy. Teachers' learning from this intensive workshop was reinforced through occasional release days and monthly grade-level workshops with professional learning communities. These additional sessions supported teachers in deepening their learning and provided space for ongoing support in implementing the new curriculum. This cycle was repeated in the second year, with an additional summer workshop and continued release days.[108]

By promoting learning over time, both within and between sessions, PD that is sustained may lead to many more hours of learning than is indicated by seat time alone.

This model not only offered teachers the opportunity to return repeatedly to the PD material over the course of a semester, but also to apply their learning within the context of their classroom between workshops. By promoting learning over time, both within and between sessions, PD that is sustained may lead to many more hours of learning than is indicated by seat time alone.

Realizing the Promise of Professional Learning Communities

This review has so far offered rich descriptions of professional development models that have incorporated various elements of effective PD. One currently popular model is the use of Professional Learning Communities (PLCs). While many professional learning community efforts have been poorly implemented and superficial in their design and impact, there is evidence that PLCs can, when implemented with a high degree of quality, support improvements in practice, along with student learning gains. Well-implemented PLCs provide ongoing, job-embedded learning that is active, collaborative, and reflective.

This section moves beyond our review of effective PD models to explore the growing body of research about the conditions under which PLCs can be an effective strategy for supporting ongoing teacher learning within and across schools.

The Benefits of Analyzing Student Work and Student Data

The examination of student work is often a focus of productive professional learning communities. Analyzing student work collaboratively gives teachers opportunities to develop a common understanding of what good work is, what common misunderstandings students have, and what instructional strategies may or may not be working and for whom.[109] For example, a study investigating three high-achieving schools that have continuously beaten the odds on standardized tests found that teachers' use of multiple student data sources to collectively reflect upon and improve instructional practices in team meetings contributed to increases in student achievement.[110]

> Analyzing student work collaboratively gives teachers opportunities to develop a common understanding of what instructional strategies may or may not be working and for whom.

While qualitative studies have sought to examine how professional communities are formed and how they operate, several large-scale studies have illustrated how collaborative, job-embedded, professional learning that is focused on student performance has resulted in changed practices and improved student achievement.[111] In a comprehensive five-year study of 1,500 restructuring schools, Newman and Wehlage (1997) analyzed three sets of data (School Restructuring Study, National Educational Longitudinal Study, and Study of Chicago School Reform) to understand how various reforms influence improved educational experiences for students.[112] In their findings, the authors linked successful professional learning communities to reduced dropout rates among students; lower absenteeism rates; and academic achievement gains in mathematics, science, history, and reading. Another finding had important implications for school equity: The particular characteristics of strong professional communities—shared intellectual purpose and a sense of collective responsibility for student learning—reduced the "traditionally strong relationship between socioeconomic status and achievement gains in mathematics and science."[113]

Learning From Professional Communities Beyond the School

Positive effects of professional communities that operate beyond the school level have also been documented by a number of researchers.[114] These are often organized via networks that connect teachers around subject matter or other shared educational concerns. Lieberman and Wood (2002) reported on the work of the National Writing Project (NWP), one of the most successful teacher networks, to understand how teacher learning in a community can be a source of efficacy and confidence in the process of adopting new practices.[115] The NWP, initially called the Bay Area Writing Project, began in 1973 as a partnership in California between the University of California, Berkeley, and local school districts. It has grown to more than 185 sites in all 50 states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands.[116] The heart of the model is the local school-university partnerships, which operate as autonomous sites to support context-specific strengths and meet context-specific challenges. "These sites are designed to be robust professional and social communities that occupy an intermediary or 'third space,' neither wholly of the university nor wholly of the school districts."[117]

> Teacher learning in a community can be a source of efficacy and confidence in the process of adopting new practices.

Despite the autonomy of the local sites, there are common design features and core principles that guide each site and are aligned with all the elements outlined above. The national network focuses on supporting the success of each local site. NWP local sites first focus on creating community among a small group of teachers during a five-week summer institute in which teachers engage in writing, share their work, and critique their peers. In the process of making their work public and critiquing others, teachers learn how to make implicit rules and expectations explicit, and how to give and receive constructive feedback for students. These summer institutes are held at each site and run by "teacher consultants" who are trained and supported by the national network.[118]

The summer institutes, which were designed to promote risk-taking and collaboration, provide a foundation for ongoing learning for teachers once they have left. These ongoing professional learning programs are collaboratively designed by schools and universities and led by teacher consultants, NWP veteran teachers. In addition, NWP provides many ways to promote active, collaborative learning within and across sites; newsletters, annual conferences, and opportunities to lead workshops are catalysts for the continuous engagement of teachers, creating the intersection of professional learning communities within the school and across the profession.[119]

An important aspect of the NWP's success is the inclusion of program research starting from the very first summer institute. NWP collects internal, site-based, practitioner-directed research, as well as external, national, and independent research that directs the evolution of its work. The following box offers study results from the NWP College Ready Writers Program.

Effective Professional Development in Practice: National Writing Project's College-Ready Writers Program

The College-Ready Writers Program (CRWP) is a National Writing Project program that focuses specifically on the argument writing of students in grades 7 through 10 by introducing teachers to new instructional practices based on higher standards for college- and career-ready writing. A two-year random assignment study of the program's implementation in 12 local Writing Project sites has demonstrated its promise for supporting student learning.[120]

SRI conducted the study of CRWP in 22 high-poverty rural districts across 10 states—Alabama, Arizona, Arkansas, Louisiana, Mississippi, Missouri, New York, Oklahoma, South Carolina, and Tennessee. Despite such geographical and contextual diversity, the CRWP was implemented with a high degree of fidelity. The study design randomly assigned 44 high-poverty rural districts to either the CRWP program or a control group. The CRWP components included: PD of at least 90 hours over two years with supports that included demonstration lessons, coaching, co-designing learning tasks, co-planning, curricular resources including lesson units for argument writing, and formative assessment tools to help teachers focus on student learning. In contrast, the control group engaged in "business as usual" PD.[121]

The program succeeded in supporting both teacher and student learning despite the challenges that high-poverty rural districts often face for implementing effective PD. CRWP was found to have a positive, statistically significant impact on three of four attributes of student writing: content, structure, and stance. The remaining attribute, writing conventions, was marginally significant. Authors of the study note, "… this study of teacher professional development is one of the largest and most rigorous to find evidence of an impact on student academic outcomes," indicating the power of high-quality PD to affect student achievement improvements at scale.[122]

There are several characteristics of the CRWP that distinguish it from many other programs and which align with research on quality PD. Three key elements are:

1. A sustained focus on learning over time with explicit modeling, engagement in, and feedback about pedagogical writing strategies.
2. A teacher-driven system that is enacted with collaboration at the center of the professional learning work.
3. Active learning focused on classroom practices with student work at the center.

Additionally, this PD is focused on a particularly complex task—using nonfiction text as the evidence for writing a well-reasoned argument.

Creating the Conditions for Effective Professional Development: Opportunities and Challenges

This review of research on professional development models that have positively impacted student learning has aimed to identify and illustrate professional learning elements in order to help shine light on powerful teacher learning experiences. Examples of PD that have raised student achievement can help policymakers and practitioners better understand what goes into quality teacher professional learning. This review does not explain, however, why some well-designed PD does not improve student achievement.[123] In this section, we consider studies both within and beyond the scope of our review to explore factors that support or complicate the implementation of effective PD. We find that conditions for teaching and learning both within schools and at the broader systems level can inhibit the effectiveness of teacher PD.

> Examples of PD that have raised student achievement can help policymakers and practitioners better understand what goes into quality teacher professional learning.

School Level

Several researchers have sought to understand why some PD has proven insufficient to affect teaching practice and raise student achievement in schools.[124] In their study of 4th to 6th grade teachers, Bucznyski and Hansen (2010) discussed several barriers to the implementation of PD.[125] They challenge the notion that PD is only as effective as a teacher's will to employ the knowledge and skills gained. They note, "… teachers that are willing to implement professional development practices in the classroom often face hurdles that are beyond their control."[126] Teachers may also face hurdles that are within their control, but which are difficult, if not impossible, to attend to, given the challenging nature of their specific school environments.

Among these barriers are a lack of time allotted to teaching curriculum that uses the newly acquired knowledge and skills; the need to teach mandated curriculum on a pacing guide; challenges of teaching English learners without specific PD to address students' learning needs; a lack of resources (such as curriculum materials, technology, or science equipment); and classroom management issues. Of these barriers, the study's authors noted that lack of resources was the largest barrier to PD implementation, commenting that teachers often have to pay for their own materials for their classrooms. As a result,

> [w]hen funds are out of pocket for teachers, a financial divide is in place for students of more affluent teachers and students of teachers whose own financial resources are limited. Other resources provided by schools, such as technology, are also limited.[127]

One teacher in the study noted on a survey, "Having to locate, borrow, or purchase items for an experiment is time consuming and not always possible."[128]

These barriers affect students and teachers in a wide range of contexts; they are of particular concern for schools and districts located in high-poverty neighborhoods where financial constraints are often particularly acute. The researchers recommend that teachers be given strategies during PD to proactively address possible obstacles as they arise.[129]

Johnson and Fargo (2010) echoed these equity challenges, discussing the specific obstacles to applying the lessons of PD in urban schools.[130] They note, "Teachers in urban schools often get caught up in the many distractions occurring on a daily basis and struggle to engage learners who are often distracted by complicated lives outside of school."[131] Crises such as school closings and the uncertainty of employment were cited as examples of the type of "turbulence" that urban science teachers faced in the course of acquiring and implementing new learning from PD opportunities.[132] These examples also demonstrate how the obstacles faced by teachers in schools may actually be manifestations of broader issues that stem from systemic problems. In the case of limited funding, for example, the learning experiences of teachers as well as students are influenced by broader policy about resource allocation.

System Level

Challenges to implementing effective PD extend beyond the school and classroom. A New America report from Tooley and Connally (2016) identified system-level obstacles to effective PD and concluded that there are four overarching areas where improvement is needed to facilitate increased effectiveness of PD.

1. **Identifying PD needs:** Teacher PD is often determined without understanding what teachers need. This shortfall is frequently exacerbated by a lack of shared vision around what excellent teaching entails. In addition, preparation and training for principals and instructional leaders often fail to address how leaders can identify and organize needs-based PD. Without systems in place to ensure teachers' needs are being identified and met, PD will not be as effective as it should be.

2. **Choosing approaches most likely to be effective:** As noted in this review, there is a reasonably strong consensus about the kind of professional learning opportunities likely to yield student achievement. Still, a great deal of PD is implemented that does not meet these standards. "One-off" workshops are easy to schedule and require less time and human capital to implement than evidence-based approaches. Teacher contracts and state recertification requirements also tend to encourage these models by emphasizing seat time as the metric for gauging engagement with PD.

3. **Implementing approaches with quality and fidelity:** Even when educators have knowledge of effective PD models, implementation presents its own obstacles. For example, a school or district may create a program that includes coaching for teachers. However, it is not sufficient to simply designate coaches and have them available for teachers; many other variables affect coaches' effectiveness. The authors note, "The coach's expertise in the teachers' grade span, subject, and/or school context; the depth of observation, feedback, and suggestions for things to try differently; the authority of a coach to recommend next steps; time and accountability for teachers to follow through with recommended next steps" have implications for the success of the program.[133] Other implementation barriers include the lack of an integrated, coherent approach to instruction and insufficient capacity.

4. **Assessing PD outcomes:** Few schools, districts, or state education agencies have created good systems of tracking PD, let alone systems for analyzing the quality and impact of PD. Without a sense of what is working and why, it is hard to adopt and implement professional learning for teachers that is evidence based and designed to address potential obstacles.[134]

Even in the case of well-designed PD, these obstacles can impede the effectiveness of professional learning and hinder its impact on student learning and achievement. The challenges with implementing and scaling evidence-based practices underscore that translating promising PD research into practice remains one area ripe for improvement.

Conclusions and Policy Implications

Professional development is an important strategy for ensuring that educators are equipped to support deep and complex student learning in their classrooms. However, research shows great variation in the extent to which PD programs accomplish this goal. This paper has examined recent studies of successful PD models that report student learning gains. We identify seven common design elements of these effective PD approaches.

1. They are **content focused**.
2. They incorporate **active learning strategies**.
3. They engage teachers in **collaboration**.
4. They use **models** and/or modeling.
5. They provide **coaching and expert support**.
6. They include time for **feedback and reflection**.
7. They are of **sustained duration**.

Across the reviewed studies, these elements have been combined in a variety of ways to support teachers' professional learning. Indeed, none of the successful programs featured attributes in isolation: As Hargreaves and Fullan (2012) note, the combination of these elements creates a collaborative culture that results in a form of collective professional capital that leverages much more productive, widespread improvement in an organization than would be possible if teachers worked alone in egg-crate classrooms.[135] Regardless of the specific model employed, PD should be well designed, incorporating elements of effective PD, as we have described. It should also be linked to identified teacher needs, should ensure that teachers have a say in the type of learning they require to best support their students, and should be regularly evaluated so that quality can be continually improved.

Implications for Policy

Supporting and incentivizing the kind of evidence-based PD we have reviewed here could be facilitated by changes in policy. For example:

- Policymakers could **adopt standards for professional development** to guide the design, evaluation, and funding of professional learning provided to educators. These standards might reflect the features of effective professional learning outlined in this report as well as standards for implementation.[136]
- Policymakers and administrators could **evaluate and redesign the use of time and school schedules** to increase opportunities for professional learning and collaboration, including participation in professional learning communities, peer coaching and observations across classrooms, and collaborative planning.
- States, districts, and schools could regularly **conduct needs assessments** using data from staff surveys to identify areas of professional learning most needed and desired by educators. Data from these sources can help ensure that professional learning is not disconnected from practice and supports the areas of knowledge and skills educators want to develop.

- State and district administrators could **identify and develop expert teachers as mentors and coaches** to support learning in their particular area(s) of expertise for other educators.
- States and districts can **integrate professional learning into ESSA school improvement initiatives**, such as efforts to implement new learning standards, use student data to inform instruction, improve student literacy, increase student access to advanced coursework, and create a positive and inclusive learning environment.
- States and districts can **provide technology-facilitated opportunities for professional learning and coaching**, using funding available under Titles II and IV of ESSA to address the needs of rural communities and provide opportunities for intradistrict and intraschool collaboration.
- Policymakers can **provide flexible funding and continuing education units** for learning opportunities that include sustained engagement in collaboration, mentoring, and coaching, as well as institutes, workshops, and seminars.

Implications for Implementation and Practice

At the same time, well-designed programs must also be implemented well to be effective. Even the best designed PD may fail to produce desired outcomes if it is poorly implemented due to barriers such as

- inadequate resources, including needed curriculum materials;
- lack of shared vision about what high-quality instruction entails;
- lack of time for planning and implementing new instructional approaches;
- conflicting requirements, such as scripted curriculum or pacing guides; and
- lack of adequate foundational knowledge on the part of teachers.

Common obstacles to PD should be anticipated and planned for during both the design and implementation phases of PD. Implementing PD well also requires responsiveness to the needs of educators and learners and to the contexts in which teaching and learning will take place.

In the end, well-designed and implemented PD should be considered an essential component of a comprehensive system of teaching and learning that supports students to develop the knowledge, skills, and competencies they need to thrive in the 21st century. To ensure a coherent system that supports teachers across the entire professional continuum, professional learning should link to their experiences in preparation and induction, as well as to teaching standards and evaluation. It should also bridge to leadership opportunities to ensure a comprehensive system focused on the growth and development of teachers.

Appendix A: Methodology

This paper builds upon an earlier review of effective teacher professional development by Darling-Hammond et al. (2009). To identify elements that are prevalent in effective PD, we reviewed the empirical literature on models that have demonstrated benefits for student learning. Our review includes studies from recent decades that use rigorous methodologies to demonstrate a positive link between teacher PD and student outcomes.

Specifically, each study included in the review either employs an experimental or quasi-experimental comparison group, or uses appropriate statistical modeling and hypothesis testing to estimate the effect of teacher PD on students' academic outcomes, with controls for context variables and student characteristics. The review includes studies that find positive, statistically significant effects of PD on student achievement. All studies included in the review appear in peer-reviewed journals, or represent rigorous, large-scale research studies submitted to federal agencies and subject to review.

We drew on Darling-Hammond et al.'s (2009) survey to identify articles published before 2010 with methodologies and findings to qualify for inclusion in the current review. We paired this approach with a thorough scan of more recent literature, using database searches to identify studies published from 2010 on that meet the criteria for inclusion. Researchers used keyword searches to cull relevant literature from Google Scholar, ERIC, EBSCO, JSTOR, and SAGE in early fall of 2016 and again in spring 2017. Key terms used in these searches include: "teacher professional development," "professional learning," "student outcomes," and "student achievement." Although we endeavored to undertake an exhaustive search of recent literature, it is possible that relevant studies have been excluded because they were not catalogued under any of the key search terms used. Appendix B details each of the 35 studies that surfaced using this method that met our methodological criteria, eight from Darling-Hammond et al. (2009) and 27 from the broader scan of recent literature.

We then reviewed these studies and qualitatively coded them for program features and characteristics. To begin this process, a researcher generated a list of deductive codes based on previous literature, including Darling-Hammond et al. (2009) and Desimone (2009). Deductive codes included, for example, *collaboration and 50+ hour duration*. After an initial reading of the papers in the review, researchers refined and expanded coding to include features that emerged from the studies, including *sustained duration, opportunities for feedback*, and *reflection on practice*. Researchers created decision rules for each of the refined codes and engaged in ongoing discussion throughout the coding process to ensure inter-coder reliability.

At times, the defined elements of effective PD can overlap. For example, collaboration can be both an active learning strategy and an element unto itself. However, it is possible to engage in active learning without structured collaboration and it is possible to engage in forms of collaboration, such as discussing a theory or idea, that do not involve active applications.

Appendix C provides an overview of the elements that were exhibited by the PD model(s) featured in each study. Two studies that otherwise met the criteria for inclusion in the review were excluded from Appendix C because they contain insufficient detail regarding the PD model to enable qualitative coding of the program elements. These studies—Wenglinsky (2000) and Desimone et al. (2013)—analyze large-scale data sets spanning a variety of contexts and, as a result, provide limited descriptions of the PD provided to teachers. However, these studies provide important evidence regarding the effectiveness of PD, so are retained in Appendix B and referred to where relevant in the body of the paper. They have been omitted from Appendix C and the counts of the prevalence of each element in the text due to limited details regarding the PD to which teachers were exposed.

We recognize that this methodology is not without limitations. Because studies of PD typically examine comprehensive models that incorporate many elements, this paper does not seek to draw conclusions about the efficacy of individual program components. We are also unable to comment on the elements of PD models that did not yield positive results on student achievement. It is conceivable that these ineffective models share one or more elements with those highlighted in this study and yet fail to produce positive effects on student achievement, perhaps due to weaknesses in content, design, or implementation. However, it is beyond the scope of this paper to detail why specific programs are unsuccessful. Rather, the study seeks to describe the characteristics of PD that research has been found to have positive relationships with student outcomes. Although the paper dedicates a section to obstacles and challenges to implementation, this remains an area worth further investigation.

Appendix B: Summary of Studies Reviewed for This Report

Note: ES is used to denote effect sizes.

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Akiba, M. & Liang, G. (2016). Effects of teacher professional learning activities on student achievement growth. *The Journal of Educational Research, 109*(1), 99–110. **Description:** Researchers analyzed three years of results from the Teachers' Opportunity to Learn (TOTL) survey of middle school mathematics teachers in Missouri. Analysis focuses on what types of professional development, as defined by the survey (standard professional development, teacher collaboration, university courses, professional conferences, informal communication, and individual learning) are associated with student achievement growth.	**Methodology:** Three-year descriptive survey analysis • *n*=467 middle school mathematics teachers in 91 Missouri schools • Student achievement measured using the Missouri Assessment Program in mathematics **Findings:** Student achievement growth rates were positively associated with school average amounts of participation in teacher collaboration, professional conferences, and informal communication with colleagues. Controlling for student characteristics and teacher qualifications, a one-hour increase in the school average amount of teacher collaboration was associated with a .01 increase in the annual growth rate in student math scores over the three years. A one-hour increase in the school average amount of teacher participation in professional conferences and informal communication were associated with increases in the annual growth rate of .15 and .23 respectively.
Allen, J. P., Pianta, R. C., Gregory, A., Mikami, A. Y., & Lun, J. (2011). An interaction-based approach to enhancing secondary school instruction and student achievement. *Science, 333*(6045), 1034–1037. **Description:** Teachers enrolled in My Teaching Partner–Secondary, a web-mediated coaching program designed to improve teacher-student interactions. Teachers participated in an initial training workshop followed by twice-monthly coaching from a remote mentor. For each coaching session, teachers were asked to submit short videos of their practice, reflect on their teaching, and respond to questions from their coach regarding the relationship between teacher practice and student engagement. Each reflection was followed by a 20- to 30-minute phone conference with the coach. Teachers also attended monthly "booster" workshops and were given access to an annotated video library for the duration of the program. Overall, the program offered 20 hours of in-service training over 13 months in addition to the time teachers spent working on the program's concepts in their classrooms.	**Methodology:** Two-year randomized controlled trial • *n*=78 secondary school teachers and 2,237 secondary students in 12 Virginia schools • Student achievement measured by Virginia state standardized tests in relevant subject **Findings:** Students whose teachers participated in the program the previous school year demonstrated gains in student achievement of .22 standard deviations (equivalent to an average increase from the 50th to 59th percentile) relative to students whose teachers had not participated.

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Allen, J. P., Hafen, C. A., Gregory, A. C., Mikami, A. Y., & Pianta, R. (2015). Enhancing secondary school instruction and student achievement: Replication and extension of the My Teaching Partner–Secondary intervention. *Journal of Research on Educational Effectiveness 8*(4): 475–489. **Description:** Teachers participated in My Teaching Partner–Secondary, a web-mediated coaching program to improve teacher-student interactions in the classroom. Teachers participated in an initial half-day training with master teachers from the research team who would go on to provide remote coaching for the duration of the program. This initial workshop focused on the dimensions of high-quality student-teacher interactions, such as teacher sensitivity and regard for student perspectives, and included videos of exemplary practice. Over the next two academic years, teachers engaged in 12 remote coaching cycles focused on student-teacher relationships, classroom organization, and instructional support. In each coaching cycle, teachers shared a video of a typical lesson with their coach, who chose short segments of the lesson to highlight for analysis and discussion. Coaches shared these segments with teachers, who were asked to examine their own practice, student responses to their practice, and the relationship between teacher practice and student reactions. This reflection was followed by a 20- to 30-minute phone conference focused on instructional strategies to strengthen interactions with students. This coaching cycle occurred every 6 weeks. The 2-year program concluded with a final booster workshop.	**Methodology:** Stratified randomized controlled trial • *n*= 86 secondary school teachers and 1,194 secondary students in a diverse urban school district. • Student achievement measured by Virginia state standardized tests in the subject areas taught by the participating teachers. **Findings:** At the end of the two-year program, students whose teachers participated demonstrated gains in achievement equivalent to an average increase from the 50th to 59th percentile relative to students whose teachers had not participated (ES = 0.48).
Antoniou, P. & Kyriakides, L. (2013). A dynamic integrated approach to teacher professional development: Impact and sustainability of the effects on improving teacher behavior and student outcomes. *Teaching and Teacher Education, 29*, 1–12. **Description:** Teachers participated in PD using either the Dynamic Integrated Approach (DIA) or the Holistic Approach (HA). Using the DIA, teachers' skills were evaluated and assigned to one of five developmental stages, with each stage focusing on increasingly complex teaching skills. The Holistic Approach examines attitudes, beliefs, and practices not limited to stages and skills. Teachers attended nine monthly sessions throughout the school year. The DIA group sessions consisted of assigning teachers' developmental stages and collaborating and creating individual action plans. Between each PD session, teachers implemented their plans in their classrooms, received feedback, and revised their plans. Teachers in the HA group reflected and discussed a problem based on attitude, beliefs, and practice. The remaining sessions were used to create, discuss implementation, and adjust an action plan with colleagues. Each monthly session lasted 3-4 hours in duration totaling 27-36 hours. Both groups completed a total of 88.5 hours of PD.	**Methodology:** Randomized controlled trial • *n*=123 3rd- to 6th-grade teachers in Cyprus schools and 131 students • Criterion-reference math tests **Findings:** Overall, the achievement of students whose teachers employed DIA was 0.34 standard deviations higher than those in the HA group. Students of teachers at stages 1 and 2 scored lower (-0.52 and -0.24 standard deviations respectively) than those of teachers at stage 3. Students of teachers at stage 4 had the highest achievement gains. Students of teachers in stage 4 of the DIA group scored 0.32 standard deviations higher than students of teachers at stage 3.

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Buczynski, S. & Hansen, C. B. (2010). Impact of professional development on teacher practice; uncovering connections. *Teacher and Teacher Education, 26,* 599–607. **Description:** Teacher PD focused on integrated, inquiry-based instruction in elementary classrooms. An Inquiry Learning Partnership (ILP) was formed between two urban school districts, a science museum, and a university to develop the professional development program for 4th- to 6th-grade trade teachers. The co-designed PD consisted of standards-based content and inquiry-based strategies. PD consisted of lectures on subject matter by university professors paired with constructivist, hands-on experiences for teachers with science kits and demonstration of inquiry practices. Science content was taught by university faculty, while pedagogy sessions were led by the ILP director and district resource teachers. Pedagogy session topics were identified as formative assessment, use of student science notebooks, unpacking standards, teaching English learners, adapting curriculum, best practices, and addressing the achievement gap. PD was administered during a 35-hour, weeklong summer institute. In addition, teachers attended at least seven of 29 available seven-hour Saturday content sessions over the course of an academic year.	**Methodology:** Quasi-experimental study within an exploratory case study • *n*=118 veteran 4th- to 6th-grade teachers across two urban districts' low-performing schools and 1,964 5th-grade students • Student achievement measured by scores on 2005 and 2006 California Standards Tests (CSTs) from grade 5 and from local assessments **Findings:** In one district, among participating teachers' students, 9% more scored proficient or advanced on the CST in 2006 than in 2005, compared to a 2% gain from teachers who did not participate in PD. In the second district, the scores of participating teachers' students were stable while those of nonparticipating teachers declined, showing a 4% drop in the percent scoring proficient or advanced. The greatest gains in student achievement occurred at sites where multiple teachers were involved in the PD.
Buysse, V., Castro, C. C., & Peisner-Feinberg, E. (2010). Effects of a professional development program on classroom practices and outcomes for Latino dual language learners. *Early Childhood Research Quarterly* 25: 194–206. **Description:** Nuestros Niños Early Language and Literacy Program is a research-based PD program focused on effective instructional practices to promote language and literacy skills for pre-k children in general, and Latinx dual language learners (DLLs) in particular. The PD was designed for monolingual teachers who used English as the language of instruction and was structured as a three-day institute conducted over several weeks, with follow-up sessions throughout the course of the year. The institute contained six modules focused on topics of literacy and DLLs. Teachers were also provided with a range of instructional strategies and suggestions for specific accommodations to facilitate the development of children's primary language in Spanish. Follow-up sessions with bilingual Latinx consultants supporting learning communities of teachers took place over the school year. During the learning communities, teachers worked collaboratively to create lesson plans and view recordings of themselves and others teaching to refine and improve their own instructional strategies for Latinx DLL children. Consultants also met with teachers one-on-one.	**Methodology:** Randomized controlled trial • *n*=55 teachers and 193 pre-k Latinx dual language learners in North Carolina's More at Four Pre-Kindergarten Program • Student achievement measured in English and Spanish on the Woodcock Language Proficiency Battery-Revised: English and Spanish Forms; the Peabody Picture Vocabulary Test and corresponding Test de Vocabulario en Emagenes Peabody; the Phonological Awareness Tasks; Naming Letters; and Where's My Teddy Story and Print Concepts **Findings:** Teachers' general language and literacy practices and those specific to Latino ELLs measurably improved. For outcomes assessed in Spanish, there were significantly greater gains for children in the intervention group than in the control group on the Phonological Awareness (ES=.69) and Rhyme matching (ES=.68) tasks.

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Campbell, P. F. & Malkus, N. N. (2011). The impact of elementary mathematics coaches on student achievement. *The Elementary School Journal, 111*(3), 430–454. **Description:** The study outlines the professional development mathematics coaches received to deliver onsite, whole-school teacher professional development in elementary schools. Coaches received specialized training in five courses focusing on mathematics content, mathematics pedagogy, and educational leadership that were designed for the program and provided through local universities. Courses were co-taught by mathematicians, and mathematics educators and coaches were provided access to course materials, video exemplars, and case studies. Coaches' coursework was completed over two years. Data from the study indicate that coaches' primary activities in their placement schools included coaching teachers and supporting assessment.	**Methodology:** Three-year randomized controlled trial • *n*=36 elementary schools in urban and urban-edge school districts • Student achievement measured by Virginia's statewide standardized achievement test in mathematics **Findings:** Assigning elementary mathematics coaches improved student achievement in grades 3-5 by .14 to .19 standard deviations in each grade level. Stronger effects on achievement were observed in grades 4 and 5 than in grade 3. The presence of a mathematics coach did not have a significant impact on student achievement during the first year of placement.
Carpenter, T. P., Fennema, E., Peterson, P. L., Chiang, C., & Loef, M. (1989). Using knowledge of children's mathematics thinking in classroom teaching: An experimental study. *American Educational Research Journal 26*(4): 499–531. **Description:** Early elementary school teachers participated in a month long summer workshop designed to enhance their understanding of children's mathematical thinking. University faculty led the workshop, which was focused on research about children's approaches to addition and subtraction and principles for its application in the classroom. Participation in the workshop earned teachers three university credits and entailed attendance at lectures and involvement in a variety of active-learning opportunities such as group discussions and workshops, unit planning, and shared analysis of curricular materials. Teachers also received free time to work on projects of their choosing, individually or with colleagues and workshop leaders as participants preferred. Following the workshop, teachers met with workshop leaders one time; teachers also had continued access to a resource person affiliated with the program throughout the year. Overall, the workshop provided 80 hours of professional development.	**Methodology:** Randomized controlled trial • *n*=40 1st-grade teachers in 24 Wisconsin schools and about 480 1st-grade students • At pre-test, student achievement was measured using the Iowa Test of Basic Skills (ITBS). At post-test, researchers used ITBS and other standardized and researcher-designed mathematics items. **Findings:** Students of teachers who participated in the workshop outperformed students of teachers who did not on three of six measures of mathematics achievement, including one measure of computation and two measures of problem solving. These students were also more inclined to be more cognitively guided in their beliefs about mathematical learning and to report greater understanding of mathematics.

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Desimone, L., Smith, T., & Phillips, K. (2013). Linking student achievement growth to professional development participation and changes in instruction: A longitudinal study of elementary students and teachers in Title I schools. *Teachers College Record, 115*(5), 1–46. This article focused on two types of professional development: content-focused and participation-focused (time spent on math instruction). Using data from the Longitudinal Evaluation of School Change and Performance (LESCP), authors aimed to answer: 1) to what extent do teachers' self-reported topic coverage and emphasis on memorization and solving novel problems, and time spent on mathematics instruction predict student growth? Does a teacher's time spent on mathematics instruction and emphasis on memorization and solving novel problems predict student growth? and 2) to what extent does teacher participation in content-focused professional development predict the aspects of instruction in the first question to be related to increases in students' achievement gains in mathematics? To what extent does participation in content-focused PD predict if a teacher will spend more time on memorization or novel problem-solving and relate to student achievement in mathematics. Researchers analyzed teachers' instructional practice and participation in professional development over three years and student academic growth over those three years.	**Methodology:** Three-year quasi-experimental study using hierarchical linear modeling • *n*=457 3rd- to 5th-grade teachers and 4,803 students in 71 high-poverty schools • Student outcomes measured by SAT-9 tests **Findings:** Student growth was 15% of a standard deviation slower than average for students whose teachers focused on basic topics and 15% of a standard deviation faster than average for students whose teachers focused on advanced topics. Growth was 7.5% of a standard deviation slower than average for students whose teachers emphasized memorizing facts. Teachers who participated in professional development that focused on math content or instructional strategies in mathematics (in Year 1) were more likely to teach in ways associated with student achievement growth; for example, they were 11% of a standard deviation more likely to teach advanced topics.
Doppelt, Y., Schunn C. D., Silk, E. M., Mehalik, M. M., Reynolds, B., & Ward, E. (2009). Evaluating the impact of facilitated learning community approach to professional development on teacher practice and student achievement. *Research in Science and Technological Education, 27*(3), 339–354. **Description:** Teachers participated in content-based collaborative inquiry (CBCI) sessions in order to receive support for a new 8th-grade science curriculum focused on electronics. Two sessions occurred prior to implementation; two during; and the final workshop occurred after the implementation as a final reflection on the unit. Teachers were engaged in activity learning situated in the curriculum—they actually engaged in the lessons just as their students would. In addition, they spent much time in the workshops reflecting on instructional activities in their classrooms. They shared student work and instructional materials, actively discussing and reflecting on instruction. In year 1 of the study, curriculum designers led the PD. Year 2, teacher leaders from the first cohort led the PD. Key elements of the PD were the opportunity for teachers to discuss students' understandings, collect and analyze data, share results with colleagues, and problem-solve instructional solutions collaboratively. In total, teachers participated in five four-hour workshop sessions.	**Methodology:** Two-year quasi-experimental study • *n*=23 8th-grade science teachers in a mid-sized urban school district • Student achievement was measured by a six-question knowledge test in year 1 and a 20-question knowledge test in year 2 of the study **Findings:** Students whose teachers participated in the PD had an advantage in achievement over those whose teachers did not. Students whose teachers used the new curriculum and participated in PD had significantly greater achievement than those students whose teachers used the new curriculum with no PD (ES=1.17). This remained true for students whose teachers continued to use the new curriculum.

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Finkelstein, N., Hanson, T., Huang, C. W., Hirschman, B., & Huang, M. (2010). Effects of problem based economics on high school economics instruction. Final report. *National Center for Education Evaluation and Regional Assistance, NCEE 2010–4002.* **Description:** PD focused on the Problem Based Economics curriculum developed by the Buck Institute for Education on 12th-graders' content knowledge measured by the Test of Economic Literacy and a performance task as opposed to a traditional lecture and textbook format. The problem-based approach allows students to reason through and solve a real-world problem through inquiry-based pedagogy. Control group and intervention teachers taught two consecutive semesters (fall and spring) of economics. Intervention teachers taught the Problem Based Economics curriculum, while the control group taught the typical course. Only student data for the spring were included in the analysis. Intervention teachers taught five of the nine modules in the problem-based curriculum. Intervention teachers participated in a five-day professional development workshop to become familiar with the module and pedagogical strategies. They were trained by current and former economics teachers. On four occasions throughout the semester, once at the beginning and throughout the module completion, teachers participated in a group conference call with developers and the study team to discuss progress and challenges and get feedback. Teachers also had the ability to call and email Buck Institute staff throughout the implementation. The PD took place for one academic school year—a five-day training and periodic check-ins throughout the school year.	**Methodology:** Within-school randomized controlled trial • *n*=64 11th- and 12th-grade economics teachers and 4,350 students in Arizona and California • Student outcomes measured by Test of Economic Literacy (TEL) and a performance task assessment **Findings:** Teachers who participated in the PD and had support in Problem Based Economics had students who scored 0.27 standard deviations higher on the TEL (on average got 2.6 test items correct) than teachers who had not participated in the PD.
Gallagher, H. A., Woodworth, K. R., & Arshan, N. L. (2017). Impact of the National Writing Project's College-Ready Writers Program in high-need rural districts. *Journal of Research on Educational Effectiveness, 1-26.* **Description:** The National Writing Project's (NWP) College-Ready Writers Program (CRWP) provided professional development to improve teaching about argument writing at the secondary level. The program used a three-part approach that included collaborative professional development, support for the implementation of new curricular resources, and formative assessment. Teachers engaged in communities of practice that included analysis of student work; participated in mini units that positioned the teachers as learners; and co-planned and co-taught NWP's argument writing curriculum, observed demonstration lessons, and engaged in reflection on their practice with teacher consultants. Formative assessments provided rapid feedback and suggested next steps to improve teacher practice. The program provided approximately 90 hours of professional development over two years. NWP provided training and support for district leaders, including one-on-one phone calls and site visits, throughout the program.	**Methodology:** Two-year district-randomized controlled trial analyzed using multilevel models • *n*=329 teachers in 44 rural, high-need districts across 10 states • Student achievement measured using an on-demand argument writing assessment **Findings:** Teacher participation in the program was associated with positive effects on the quality of student writing. Researchers documented positive, statistically significant effects on three out of four student writing attributes measured: content (ES=.20), structure (ES=.20), and stance (ES=.15). The remaining attribute, writing conventions, was marginally significant (ES=.12).

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Gersten, R., Dimino, J., Jayanthi, M., Kim, J. S., & Santoro, L. E. (2010). Teacher study group: Impact of the professional development model on reading instruction and student outcomes in first grade classrooms. *American Educational Research Journal 47*(no. 3): 694–739. **Description:** The focus of this study was a Teacher Study Group (TSG) PD model with a focus on 1st-grade teachers' reading comprehension and vocabulary instruction. Teachers in the TSGs met to discuss readings on research-based for teaching "at-risk" students and how to implement the strategies into their own teaching. Teachers collaboratively planned lessons using strategies they read and discussed. Teachers actively engaged in facilitator-guided problem-solving discussions and applied learning activities using a recursive process: (1) debrief previous application of the research, (2) walk through the research, (3) walk through the lesson, and (4) use collaborative planning. This PD took place over 16 sessions (twice a month) October to June. The sessions lasted approximately 75 minutes each. In between sessions, teachers practiced and reflected upon the strategies in their classrooms.	**Methodology:** Randomized controlled trial • *n*=81 1st-grade teachers and 468 students from three large urban school districts across three states • Student achievement in comprehension and vocabulary achievement were measured by three Dynamic Indicators of Basic Early Literacy Skills (DIBELS) tests, two subtests of the Woodcock Diagnostic Reading Battery (WDRB), and for a subset of participants, the California Achievement Test. **Findings:** Positive effects of the treatment were found on teachers' knowledge and practices in the TSG sample. Controlling for initial performance on letter fluency measures, teacher knowledge and practice factors were significantly and positively related to all of the student outcome measures. Despite small sample sizes, significant differences between the treatment and control groups on reading outcomes emerged on the California Achievement Test (ES=.20), and marginally significant effects were found on students' oral vocabulary (ES=.44). Effects were noticeable (.21, .21, and .23), though non-significant, for the Letter-Word Identification, Reading Vocabulary, and Oral Reading Fluency subtests, respectively.

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Greenleaf, C. L., Hanson, T. L., Rosen, R., Boscardin, D. K., Herman, J., & Schneider, S. A. (2011). Integrating literacy and science in biology: teaching and learning impacts of reading apprenticeship professional development. *American Educational Research Journal, 48*(3), 647–717. **Description:** High school biology teachers participated in professional development integrating academic literacy and biology instruction through Reading Apprenticeship. The program was inquiry-based, subject-focused, collaborative, and designed to address teachers' conceptual understandings as well as pedagogical content knowledge. The sessions were designed to immerse teachers in the types of learning activities and environments they would then create for their students. They engaged in activities to simulate their own discipline expertise in relation to literacy, and they also engaged in analysis of texts to identify potential literacy challenges to learners. In addition, teachers analyzed student work, videotaped classroom lessons, and studied cases of student literacy learning designed to foster high expectations of student learning. Metacognitive routines such as think-alouds and reading logs for science investigations were also used in professional development sessions. In the sessions, teachers practiced classroom routines to build student engagement), student collaboration (e.g., think-pair-share, jigsaws, and text-based student discussion and problem- solving (e.g., text annotation). Metacognitive reflection after each session focused on the impact of these sessions on teachers' learning and potential impact on their students' development. The 10 professional development sessions took place over the course of a year. An initial five-day institute took place the first summer of the study. This was followed by two follow-up days of professional development during year 1, and a final three-day follow-up occurred the summer following the academic year. During the study year, participants engaged in collaboration on a listserv moderated by professional development coaches, including the exchange of resources.	**Methodology:** Group-randomized experimental study utilizing hierarchical linear modeling • *n*=105 California high school biology teachers in underserved public high schools • Student learning measured using California states tests of English language arts, reading comprehension, and biology **Findings:** Students in treatment classrooms performed better than controls on state standardized assessments in English language arts (ES=0.23), reading comprehension (ES=0.24), and biology (ES=0.28). Treatment classes performed about a year ahead of the control classes at the end of the study. Effect sizes for white students in treatment classrooms ranged from 0.33 to 0.40 and for English learners from 0.18 to 0.23. Positive impacts were also found on ELA and biology test scores of Latinx students, although these were not statistically significant. No significant test score differences were found for African American students across classroom types. Test scores for reading comprehension and biology were higher in intervention schools than in control schools for both males and female students.

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Heller, J. I., Daehler, K .R., Wong, N., Shinohara, M., & Miratrix, L. W. (2012). Differential effects of three professional development models on teacher knowledge and student achievement in elementary science. ***Journal of Research in Science Teaching, Vol. 49, No. 3, pp. 333–362.*** **Description:** This PD focused on pedagogical science content knowledge for elementary teachers, utilizing three different interventions. One group of teachers analyzed prestructured written teaching cases. These cases were drawn from actual classrooms and written by teachers. Thus, it was an analysis of practice approach, which incorporated student work analysis, student teacher dialogue analysis, and teacher thinking and behaviors. Teachers also engaged in the same scientific investigations written about in the cases during their PD sessions. Embedded in this PD was identifying the logic behind common scientific misunderstandings, analyzing teachers' instructional choices, and considering teaching implications for their own students. A second group analyzed their own student work in relation to their teaching. Teachers in this intervention experienced carefully structured, collaborative analysis of their own students' work, which was derived from a common unit they taught. Discussion protocols for the analysis of student work were employed, which focused teachers' analysis on student understanding of content. In addition, these sessions also focused on the analysis of tasks to identify characteristics that support formative assessments to elicit information about student thinking and make instructional decisions based on student thinking. A third group utilized metacognitive analysis of their own learning experience. This took the form of reflective discussions about their own learning processes as they engaged in science content activities. The course was designed to help teachers identify concepts they found challenging to learn, examine the logic behind their own common misunderstandings of the content, and analyze the roles of hands-on investigations, discourse, and inquiry in science learning. Expert staff developers delivered a series of three courses (one PD was delivered in eight three-hour sessions, for a total of 24 contact hours with a facilitator).	**Methodology:** Randomized controlled trial • *n*=256 4th-grade teachers and 7,000 students across six states • Student outcomes measured by achievement tests developed in prior analyses of the PD; includes selected-response items and written justifications for answers **Findings:** Students of teachers who participated in PD had significantly greater learning gains on standardized tests than those who had teachers who did not participate, with average gains of 19-22 percentage points on the assessments compared to 13 points for control students. Effect sizes ranged from .4 to .8 over the two-year study. Teachers who participated in the PD focused on student work analysis had students who improved their scores significantly compared to controls. In the follow-up year, students of both those teachers and teachers who focused on cases had significantly higher test score gains. Those teachers who focused on metacognitive analysis did not improve students' written justifications as compared to the controls in either year. English language learner student scores were raised by approximately 18 percentage points in all three interventions—all three significantly higher than the average 7.1 percentage points gained in the control group.

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Johnson, C. C. & Fargo, J. D. (2014). A study of the impact of transformative professional development on Hispanic student performance on state mandated assessments of science in elementary school. *Journal of Elementary Science Teacher Education 25:* 845–859. **Description:** Elementary school science teachers participated in a professional development program to improve science instruction and facilitate culturally relevant pedagogy. The two-year program began with a two-week summer workshop that included graduate-level coursework on teaching elementary science, as well as orientation to a new science curriculum and culturally relevant pedagogy. During the second summer, the workshop focused on teaching elementary science and learning conversational Spanish. Professional development was reinforced through occasional release days and monthly grade-level workshops with professional learning communities. Over 2 years, the program provided 224 hours of professional development.	**Methodology:** Three-year case study drawn from a cluster randomized, controlled trial • *n*=21 teachers in two elementary schools in a large urban school district in a southwestern state • Student science achievement was measured by performance on a state-mandated science assessment. **Findings:** Students attending the school whose teachers participated in the PD program demonstrated significantly larger improvements in science achievement over time relative to students who attended the school with business-as-usual PD for their teachers.
Johnson, C. C. & Fargo, J. D. (2010). Urban school reform enabled by transformative professional development: Impact on teacher change and student learning of science. *Urban Education, 45*(1), 4–29. **Description:** Middle school science teachers working in an urban school district participated in a professional development program to strengthen standards-based instruction and foster culturally responsive teaching. The hands-on, whole-school program began with a two-week summer institute designed to foster relationship-building among teachers and introduce a new science curriculum and culturally responsive teacher strategies. Throughout the first year of the program, teachers attended monthly workshop days to refine the curriculum to better meet the needs of their students and undertook peer observations, providing positive and constructive feedback to colleagues. In the second year of the program, teachers attended a three-day summer session and additional monthly release days, and conducted home visits to deepen relationships with students and families. In total, the program offered nearly 200 hours of professional development, with 120 hours in the first year and 77 hours in the second.	**Methodology:** Two-year quasi-experimental study • *n*=16 middle school science teachers from four schools in one urban district • Student science achievement was measured using specially designed assessments. **Findings:** Students of teachers participating in the PD demonstrated significantly larger growth in science achievement than students at control schools in the second year of the program, with gains twice as large as those of students in the control schools.

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Kim, J. S., Olson, C. B., Scarcella, R., Kramer, J., Pearson, M., van Dyk, D., Collins, P., & Land, R. E. (2011) A randomized experiment of a cognitive strategies approach to text-based analytical writing for mainstreamed Latino English language learners in grades 6 to 12. *Journal of Research on Educational Effectiveness* 4(3): 231–263. **Description:** Secondary English teachers participated in the Pathway Project to improve their ability to employ cognitive strategies to support English language learners' interpretive reading and analytical writing skills. Through the program, teachers learn to structure analytical writing activities by engaging in revisions to an on-demand writing assessment completed by students. The program began by introducing teachers to a cognitive strategies tool kit for supporting students' reading and writing in association with literacy texts. Subsequent sessions focused on analyzing student performance, strengths, and needs through writing assessments; collaboratively designing lessons incorporating cognitive strategies for literature instruction; and setting goals for future years. These sessions were complemented by monthly meetings at each school led by literacy coaches and designed to support teachers in implementing Pathway strategies. The program also provided curricular materials aligned with cognitive approaches to literature instruction, accompanied by guidance for implementing them in teachers' classrooms. Overall, teachers participated in six full-day professional development sessions and five after-school sessions, for a total of 46 hours of professional development throughout the school year.	**Methodology:** Cluster randomized controlled trial analyzed using hierarchical linear modeling • *n*=103 secondary English teachers and more than 2,000 students in a large, urban school district • Student achievement measured using an on-demand writing assessment and the California Standards Tests for English language arts **Findings:** Students of teachers who participated in the Pathway Project performed significantly better (ES=.35) on an on-demand text-based analytical writing assessment and on the overall state standardized test of English language arts (ES=.07), after controlling for initial performance. On the on-demand writing assessment, 22% of students of participating teachers received at least two scores of 4 or above (out of 6), as compared to 14% of students in the control group. On the state standardized test, students of participating teachers scored on average 3 percentage points higher.

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Kleickmann, T., Trobst, S., Jonen, A., Vehmeyer, J., & Moller, K. (2016). The effects of expert scaffolding in elementary science professional development on teachers' beliefs and motivations, instructional practices, and student achievement. *Journal of Educational Psychology, 108*(1) 21–42. **Description:** PD focused on implementing a social constructivist approach to elementary science teaching through educational curriculum materials (ECM). Three groups of teachers participated in PD, each group with a different level of scaffolding (support for their learning through ECM). One group used the ECM materials with no expert scaffolding. Two other groups received 16 all-day workshops of PD to supplement the use of ECM. The first six (38 hours) focused specifically on floating and sinking. The 10 additional workshops (62 hours) focused on the other 10 topics. The focus of the workshops was to develop content and pedagogy. The "high scaffolding" group of teachers engaged in active learning activities such as scientific investigations, providing counter examples, developing analogies, and engaging in discussions. In general, the PD the teachers received mimicked the process by which they were to guide their elementary students. Teachers were also prompted to reflect on their own learning processes and to consider their own naïve science conceptions to help them understand the need to construct learning to fit students' existing schema. In addition, expert helped teachers to understand sequencing of science concepts to facilitate student learning. In contrast, the "low scaffolding" group of teachers received little of this support. Instead, the expert PD coach demonstrated a series of lessons on floating and sinking in a 3rd-grade classroom without scaffolding teachers' content and pedagogical knowledge. Teachers observed these lessons and conducted pre- and post-interviews with students. They were encouraged to discuss their observations in relation to the student interviews. The PD spanned approximately five months, with scaffolded groups receiving an additional 100 hours of PD during this time.	**Methodology:** Two-year quasi-experimental study • *n*=73 elementary science teachers and 1,039 3rd and 4th-grade students • Student achievement was measured through an assessment of students' conceptual understanding of floating and sinking **Findings:** Students taught by teachers who received "high scaffolding" exhibited significantly higher achievement than did students taught by "low scaffolding" teachers (ES=.45). Student achievement for both "high scaffolding" and "low scaffolding" teachers significantly surpassed achievement in classes taught by teachers with no scaffolding (ES=.55).

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Kutaka, T. S., Smith, W. M., Albano, A. D., Edwards, C. P., Ren, L., Beattie, H. L.., Lewis, W. J., Heaton, R. M., & Stroup, W. W. (2017). Connecting teacher professional development and student mathematics achievement: A four-year study of an elementary mathematics specialist program. *Journal of Teacher Education, 68*(2), 140–154. **Description:** *Primarily Math*, a mathematics professional development model for kindergarten to 3rd-grade teachers, consisted of two weeklong summer institutes involving university coursework and long-term projects assigned over the course of the school year. The PD involved collaborative assignments, self- and group reflection of video evidence, and unit planning for use in teachers' classrooms. In total, teachers participated in a minimum of 160 contact hours across two institutes in addition to time implementing PD pedagogy and practice during the school year. The PD program occurred across 13 months.	**Methodology:** Three-year quasi-experimental study using hierarchical linear modeling • *n*= 184 k-3rd-grade teachers from three large, urban school districts in Nebraska • Student achievement was measured using the Test of Early Mathematics Ability-Edition 3 (TEMA-3). **Findings:** Students of *Primarily Math* teachers had math change scores significantly greater than students of comparison teachers.
Landry, S. H., Swank, P. R., Smith, K. E., Assel, M. A., & Gunnewig, S. B. (2006) Enhancing early literacy skills for preschool children: Bringing a professional development model to scale. *Journal of Learning Disabilities 39*(4): 306–324. **Description:** Head Start educators took part in a professional development program to enhance instruction in support of improved language and early literacy skills for young children. The program began with a four-day, small-group workshop focused on strategies for supporting language enrichment and early literacy growth. The workshop relied on interactive strategies such as guided discussion, group problem-solving, and role-playing. Following the workshop, specially trained mentors conducted ongoing training sessions throughout the school year. Educators also received one hour of coaching per week from the mentors in their first year of training. Teachers who continued in the program for a second year participated in a two-day refresher course and received one hour of coaching biweekly, as well as ongoing training.	**Methodology:** Two-year quasi-experimental study • *n*=750 Head Start educators and 5,728 children in 20 urban and rural centers across Texas • Child outcomes were measured using five instruments—four standard assessments of early literacy and a specially designed social-emotional development scale **Findings:** Researchers identified greater gains in language and literacy skills for children whose teachers participated in professional development, although results varied by program site. In year 1 of the study, researchers observed moderate to large positive associations between teacher professional development and children's early literacy and language skills at 20% to 40% of sites, depending on the measure. In year 2 of the study, moderate to large effect sizes were observed in between 20% and 68% of sites.

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Landry, S. H., Anthony, J. L., Swank, P. R., & Monseque-Bailey, P. (2009) Effectiveness of comprehensive professional development for teachers of at-risk preschoolers. *Journal of Educational Psychology 101*(2), 448–465. **Description:** Early childhood educators participated in professional development to enhance teachers' ability to promote children's language and literacy development. Through the program, educators participated in a facilitated online course focused on language and literacy instruction, eCIRCLE. The facilitated course included videos of model lessons, interactive message boards, and opportunities to plan lessons and practice skills in small groups. Participating educators also received a supplemental curriculum on preschool language and literacy skills and were encouraged to use ongoing monitoring of student progress. Teachers participated in four hours of coursework per month throughout the school year. In addition, some teachers received detailed feedback on children's language and literacy progress that was linked to curricular activities and/or two-hour, on-site mentoring sessions twice per month.	**Methodology:** Randomized controlled trial • *n*=262 early childhood educators and up to eight children per classroom in 158 schools in Florida, Maryland, Ohio, and Texas • Student outcomes measured through a standardized vocabulary assessment **Findings:** Collectively, students of educators in all four professional development groups demonstrated greater gains in phonological awareness than students of educators in the control group (ES=0.14). Students of teachers who received both mentoring and detailed, instructionally linked feedback on children's language and literacy progress experienced the greatest gains in a variety of language and literacy outcomes. This included greater gains than students whose teachers received business-as-usual professional development on expressive vocabulary (ES=0.19) and print and letter knowledge (ES=0.26).
Lara-Alecio, R., Tong, F., Irby, B. J., Guerrero, C., Huerta, M., & Fan, Y. (2012). The effect of an instructional intervention on middle school English learners' science and English reading achievement. *Journal of Research in Science Teaching, 49*(8), 987–1011. **Description:** Teachers engaged in on-site, small-group professional development to promote inquiry-based, literacy-integrated instruction to improve English learners' science and reading achievement. Through the program, teachers and paraprofessionals participated in workshops where they reviewed upcoming lessons, discussed science concepts with peers, engaged in reflections on student learning, participated in inquiry activities as learners, and received instruction in strategies for teaching English learners. Researchers also provided teachers with lessons plans that incorporated strategies for effective instruction of English learners. Teachers met biweekly for three-hour sessions, receiving six hours of professional development per month; paraprofessionals met monthly for three hours. The program also included a focus on new and enhanced instructional activities for English learners.	**Methodology:** Quasi-experimental study • *n*=246 5th-grade teachers and 166 students in four lower middle schools in an urban district in southeast Texas • Student achievement was measured by performance on science and reading district and state tests and Dynamic Indicators of Basic Early Literacy Skills (DIBELS) **Findings:** Treatment group students scored significantly higher scores on the DIBELS than control group students. In addition, students of teachers who participated in PD earned passing and commended scores on district science and reading benchmarks at higher rates than students of those who did not participate (ES=0.127 - .238). A similar pattern was observed for reading achievement on the state test, with an average passing rate of 69% in the treatment group and 60% in the control group.

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Marek, E. & Methven, S. B. (1991). Effects of the learning cycle upon student and classroom teacher performance. *Journal of Research in Science Teaching, 28*(1), 41–53. **Description:** Elementary science teachers participated in a monthlong in-service workshop designed to support the adoption of a new approach to science instruction. The workshop aimed for participants to understand that science is a process, or "search for knowledge," rather than a body of knowledge, and that students who learn science as a search for knowledge construct their own understandings about the world. It was also designed to help teachers learn how to develop "learning cycles," an approach to curriculum that is compatible with approaching science as a process or method. During the workshop, teachers experienced several learning cycles as learners; this involved gathering data, identifying key concepts from the data, and expanding their understanding by applying the concept to other topics. Teachers then taught each other using learning cycles from a provided curriculum before preparing their own learning cycles for use in the classroom. All teachers agreed to use learning cycles in their classrooms following the workshop. The workshop offered 100 hours of in-service training over four weeks.	**Methodology:** Quasi-experimental matched pairs design • *n*=27 elementary science teachers and 226 k- to 5th-grade students • Student outcomes were measured using three Piagetian conservation tasks, a measure of cognitive development, and an analysis of descriptive language used by students during interviews. **Findings:** Students of treatment group teachers demonstrated significantly greater growth in their conservation reasoning abilities than control group teachers. Treatment group students also demonstrated enhanced quality and quantity of descriptive language relative to control group students.
May, H., Sirinides, P., Gray, A., & Goldsworthy, H. (2016). *Reading Recovery: An Evaluation of the Four-Year i3 Scale-Up.* Philadelphia, PA: Consortium for Policy Research in Education. **Description:** Educators participated in an intensive yearlong graduate-level training course in order to teach Reading Recovery, an intervention targeted at struggling 1st-grade readers. In support of teachers receiving the PD are literacy coaches who conduct the training course and university faculty who support implementation. Training is designed to enhance a teacher's ability to identify students' strengths and needs, and to facilitate his or her learning by helping students develop a set of self-regulated literacy strategies that govern the use of meaning, structure, letter-sound relationships, and visual cues in reading and writing. Once trained, teachers provided students with individual, daily 30-minute lessons over the course of a 12- to 20-week period.	**Methodology:** Parallel randomized controlled trial and quasi-experimental study • *n*=1,122 schools across the country in a wide variety of locales (e.g., urban, rural, suburban) and 6,888 students • Student achievement was measured using Iowa Test of Basic Skills (ITBS) Reading Total assessment and the state 3rd-grade reading exam. **Findings:** For each set of reading scores, the treatment group's performance was one-third to one-half standard deviation larger than that of the control group.

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
McGill-Franzen, A., Allington, R. L., Yokoi, L., & Brooks, G. (1999). Putting books in the classroom seems necessary but not sufficient. *The Journal of Education Research* 93(2):67–74. **Description:** Kindergarten teachers participated in a training program to enhance their use of books in classroom lessons. Training sessions spanned topics such as classroom organization, read-aloud techniques, story-related lesson plans, and play-based literacy activities. Participating teachers also received a large supply of books for classroom libraries and students' home libraries. Overall, teachers participated in 30 hours of training, including three daylong workshops and seven shorter meetings.	**Methodology:** Stratified randomized controlled trial • *n*=18 kindergarten teachers and 377 children from six schools in a single large eastern urban school district • Student outcomes measured using two widely used early literacy instruments **Findings:** Students of teachers receiving training and books demonstrated higher scores and larger gains on all early literacy measures than did students of teachers who did not receive training. In all but one case, these differences were statistically significant.
Meissel, K., Parr, J. M., & Timperley, H. S. (2016). Can professional development of teachers reduce disparity in student achievement? T*eaching and Teacher Education 58*, 163–173. **Description:** New Zealand schools participated in a flexible whole-school professional development model designed to improve student literacy, particularly for low-performing students. Participating schools each selected a focus on either reading or writing for the duration of the two-year project and were assigned an expert literacy facilitator to provide professional development for teachers and school leaders. Facilitators visited each school biweekly to conduct classroom observations, model literacy instruction, provide coaching and feedback, and engage in discussion and other activities with school staff. Facilitators also trained a literacy leader at each school who provided additional support for their colleagues. The project provided resources such as classroom observation and facilitation tools, as well as training and feedback for the expert facilitators throughout the two-year period.	**Methodology:** Quasi-experimental design utilizing hierarchical linear modeling • *n*=22,506 middle school students in 195 New Zealand schools • Student achievement was measured by a New Zealand standardized assessment **Findings:** Students attending schools participating in the project outperformed a nationally normed sample, especially in writing. Students in schools with a focus on improving writing improved at 2.9 to 3.5 times the expected rate (1.15 to 1.4 standard deviations). Students in schools with a focus on improving reading improved at 1.4 to 1.6 times the expected rate (0.72 to 0.85 standard deviations). Learners from all groups (defined by gender, ethnicity, and socioeconomic status) outperformed expectations based on national norms.
Meyers, C. V., Molefe, A., Brandt, W. C., Zhu, B., & Dhillon, S. (2016). Impact results of the eMINTS professional development validation study. *Educational Evaluation and Policy Analysis, 38*(3), 455–476. **Description:** Teachers participated in the Enhancing Missouri's Instructional Networked Teaching Strategies (eMINTS) professional development program. The goal of eMINTS is to help teachers develop student-centered, purposeful instruction fostered by technology utilization. While the comprehensive program involves whole-school PD elements, the bulk of the program is focused on the development of teachers. Specifically, teachers engaged in approximately 240 hours of PD over the course of two academic years through formal training sessions, a model school site visit, within-building communities of practice, and individualized coaching sessions. Some study schools also received an additional year of Intel Teach courses and online tools to support eMINTS learning.	**Methodology:** Three-year cluster randomized controlled trial • *n*=60 high-poverty, rural Missouri middle schools • Student achievement was measured using Missouri Assessment Program (MAP) in communication arts and mathematics and the 21st-Century Skills Assessment. **Findings:** Student test scores on MAP mathematics tests increased significantly more (0.128 to 0.178 standard deviations) than the control group. Results on MAP communication arts and 21st Century Skills scale scores were not statistically significant.

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Newman, D., Finney, P. B., Bell, S., Turner, H., Jaciw, A., Zacamy, J. L., & Gould, L. F. (2012). *Evaluation of the Effectiveness of the Alabama Math, Science, and Technology Initiative (AMSTI).* Washington, DC: Institute for Education Sciences. **Description:** 4th- to 8th-grade teachers engaged in the Alabama Math, Science, and Technology Initiative (AMSTI), a two-year schoolwide intervention intended to improve student achievement by better aligning classroom practices with national and statewide teaching standards by providing professional development, access to materials and technology, and in-school support for teachers. The PD includes a 10-day summer institute, follow-up training during the school year, access to program and curriculum materials, and mentoring and coaching by lead teachers and site specialists.	**Methodology:** Two-year cluster randomized controlled trial • *n*=82 Alabama middle schools • Student achievement was measured using SAT-10 tests and the Alabama Reading and Mathematics Test. **Findings:** On the SAT-10 mathematics test, students in AMSTI schools scored 0.05 standard deviations higher than their counterparts in non-PD schools, equivalent to about 28 additional days of student progress. In a separate two-year exploratory analysis, AMSTI students increased their math scores by 0.10 SD and their science scores by 0.13 SD more than control groups.
Penuel, W. R., Gallagher, L. P., & Moorthy, S. (2011). Preparing teachers to design sequences of instruction in earth systems science: A comparison of three professional development programs. *American Educational Research Journal, 48*(4), 996–1025. **Description:** Middle school science teachers in a large urban school district participated in one of three professional development programs designed to improve student science learning. The programs all used an approach to curriculum design known as *Understanding by Design* that helps teachers plan by identifying learning goals, designing or using assessments to gauge student performance relative to those goals, and offering activities to further develop student understanding. Each of the professional development models intentionally incorporated features that have been suggested by research to be part of high-quality professional learning programs, including the use of hands-on, collaborative learning strategies and opportunities to deepen content knowledge and understandings of student science thinking. Each program was also aligned with district standards and goals for science education. The groups varied in the degree to which teachers received guidance in selecting curricular materials and explicit instruction in the pedagogical models underlying curriculum. Some teachers received explicit training in instruction and assessment techniques that are associated with the use of an *Understanding by Design* approach. Others were provided and asked to use an NSF-funded middle school science curriculum. The final group received training in techniques associated with *Understanding by Design* and were provided the new curricular materials, which they were asked to use at least 50% of the time. Teachers in each of the three programs attended a two-week summer workshop, plus 4 additional development days during the school year.	**Methodology:** Cluster randomized controlled trial • *n*=53 middle school science teachers and 1,550 students in a single urban district in the American southeast • Student science learning was measured through specially designed unit tests **Findings:** Students of teachers who received explicit instruction regarding teaching models performed better than students whose teachers did not receive such instruction (*d*=0.29-0.34). Students of teachers who only received guidance in selecting curricular materials did not perform significantly differently than students whose teachers received business-as-usual professional development.

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Polly, D., McGee, J., Wang, C., Martin, C., Lambert, R., & Pugalee, D. K. (2015) Linking professional development, teacher outcomes, and student achievement: The case of a learner-centered mathematics program for elementary school teachers. *International Journal of Education Research* 72, 26–37. **Description:** Elementary math teachers engaged in a PD program to bolster standards-based elementary math instruction. The program was designed to be learner-centered, offering active learning opportunities that are collaborative, owned by teachers, supportive of changes in classroom practice, and that foster pedagogical and content knowledge. Teachers participated in a number of activities, including a summer workshop, follow-up workshops during the academic year, and classroom-embedded professional development activities. All activities were coordinated by a project team that included a mathematics professor, mathematics education professors, and school leaders. The program provided approximately 80 hours of professional development over 10 months.	**Methodology:** Three-year nonexperimental study • *n*=291 elementary mathematics teachers from two school districts: one large urban district and a nearby suburban district • Student outcomes were measured using curriculum-based assessments. **Findings:** Results from three years of program data indicate students of teachers who participated in the program consistently experienced significant gains in mathematics from pre- to post-test, mediated by teachers' mathematical knowledge for teaching. The mean gain from pre to post test in Year 1 was 29.74 (SD=35.05). The mean gain from pre to post test in Year 2 was 37.40 (SD=35.35) and from pre to post test in year 3 was 41.35 (SD=35.70).
Powell, D. R., Diamond, K. E., Burchinal, M. R., & Koehler, M. J. (2010). Effects of an early literacy professional development intervention on Head Start teachers and children. *Journal of Educational Psychology, 102*(2), 299–312. **Description:** Early childhood educators received PD in early literacy teaching from expert coaches. Educators attended a two-day workshop that was designed to foster relationship-building between coaches and educators and featured demonstrations and guided discussions of program content. Coaches then observed educators biweekly and provided teachers feedback related to early literacy instruction. Coaching was done either onsite or remotely. Onsite coaches observed educators for approximately 90 minutes, then met for 30 minutes to debrief the observation and provide oral and written feedback. For remote coaching, educators submitted 15-minute video clips and coaches provided detailed written feedback supported by links to video exemplars and other materials available through the program. The semester-long program included 16 hours of workshop and seven coaching sessions.	**Methodology:** Two-year randomized controlled trial • *n*=88 educators in 24 Head Start centers serving urban and nonurban counties in a midwestern state, with approximately eight students per classroom • Student achievement was measured using seven instruments, including the Peabody Picture Vocabulary Test-III and the Woodcock-Johnson III Tests of Achievement **Findings:** Teachers who participated in the coaching program demonstrated target practices at significantly higher levels. Students of teachers who participated in the coaching program showed significantly larger gains and better performance on four out of seven outcomes measured by the study: letter knowledge (*ES*=0.29), print concept (*ES*=.22), writing (*ES*=.17), and blending skills (*ES*=0.18).

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Roth, K. J., Garnier, H. E., Chen, C., Lemmens, M., Schwille, K., & Wickler, N. I. Z. (2011). Videobased lesson analysis: Effective science PD for teacher and student learning. *Journal on Research in Science Teaching, 48*(2),117–148. The Science Teachers Learning through Lesson Analysis (STeLLA) PD was a videobased analysis of a practice program for upper elementary teachers designed to help them analyze science teaching and learning to improve pedagogy. Two groups participated in the study. Both groups received the same science content instruction from university scientists during a three-week summer institute. STeLLA participants also engaged in video analysis of teaching during the summer institute and in follow-up sessions across the school year utilizing the Student Thinking and Science Content Storyline Lenses. The Student Thinking portion of PD focused on understanding students' ideas for use in planning, teaching, and analysis of teaching, particularly in anticipating student thinking to assist teachers in responding to students' ideas and misunderstandings in productive ways. The Science Content Storyline portion of the PD focused on the sequencing of science ideas to help students construct a coherent "story" that makes sense to them. STeLLA teachers met in small groups facilitated by STeLLA program leaders and discussed video cases of teaching that could include video(s) of one classroom, student and teacher interviews, teacher materials, and student work samples. STeLLA teachers also taught a set of four to six model lessons themselves and analyzed their teaching using a structured protocol. Purposes of these lessons were identified as: 1) modeling and scaffolding of the two lenses; 2) clarify science content understandings; and 3) provide common curriculum for lesson analysis work. Half of a study group would teach the lessons and the entire group would collaboratively analyze the teaching and student work, and then revise the lessons for the other half to use. The roles would then switch and the second half of the group would teach the lessons that would be used for analysis. The analysis was highly scaffolded by the PD facilitators. STeLLA groups met for 58 hours of analysis across the school year, in addition to 44 hours during the three-week summer session for a total of 102 hours. Content-only teachers received just the 44 hours of PD.	**Methodology:** Quasi-experimental comparison group study design • *n*=48 urban California upper elementary teachers of 1,490 students • Student achievement was measured by pre- and post-tests of student content knowledge. **Findings:** STeLLA teachers' students showed greater gains than non-STeLLA teachers' students. For a typical student taught by a STeLLA teacher, higher average achievement was associated with: • Teachers' science content knowledge (ES =.20) • Teachers' ability to analyze science teaching about student thinking (ES =.18) • Teachers' classroom use of Science Content Storyline strategy; selecting and using content representations matched to the main learning goal (ES=.32)

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Saxe, G. B,, Gearhart, M., & Nasir, N. S. (2001). Enhancing students' understanding of mathematics: A study of three contrasting approaches to professional support. *Journal of Mathematics Teacher Education 4:* 55–79. **Description:** Upper elementary school teachers participated in a reform-oriented professional development program designed to enhance student understanding of fractions. The program began with a five-day summer institute, followed by biweekly meetings for the remainder of the school year. Program meetings targeted teachers' own mathematical content knowledge, their understanding of students' mathematical thinking and motivation, and their competence in the use of integrated assessments. The meetings utilized individual and collaborative work, and active-learning strategies such as role-playing. Teachers participating in the program were also provided with two lessons from a reform mathematics curriculum to implement in their classrooms.	**Methodology:** Quasi-experimental design utilizing ANCOVA analyses • *n*=23 upper elementary school teachers • Student knowledge of fractions was measured using a specially designed test with both conceptual and computational items. **Findings:** Teacher participation in the professional development program was associated with higher student achievement on the conceptual portion of the fractions test. There was no difference on the computational portion of the fractions test.
Shaha, S. H. & Ellsworth, H. (2013). Predictors of success for professional development: Linking student achievement to school and educator successes through on-demand, online professional learning. *Journal of Instructional Psychology 40(*1): 19–26. **Description:** Educators participated in online, on-demand professional development through a web-based commercial product featuring teacher resources such as videos and online forums. In each participating school, teachers averaged at least 90 minutes of video viewing on the PD platform, though teachers in higher engagement schools averaged six hours of viewing and teachers in lower engagement schools averaged three hours. Through the platform, teachers had the opportunity to answer follow-up and reflection questions about content, create focus objectives, and join interactive user forums and communities.	**Methodology:** Two-year quasi-experimental design • *n*=734 schools in 39 states • Student achievement was measured by students achieving proficient or advanced ratings on standardized math and reading tests. **Findings:** Students at schools with higher average engagement with the PD program improved reading achievement at four times the rate of students at schools with lower average engagement and improved math achievement at 30 times the rate of students at low-engagement schools.

Study and Professional Development Description	Study Methodology and Findings Related to Student Outcomes
Taylor, J. A., Roth, K., Wilson, C., Stuhlsatz, M., & Tipton, E. (2017). The effect of an analysis-of-practice, videocase-based, teacher professional development program on elementary students' science achievement. *Journal of Research on Educational Effectiveness, 10*(2), 241–271. **Description:** 4th- to 6th-grade science teachers used STeLLA—an analysis-of-practice, videocase-based, professional development program to improve student science learning. The treatment group consisted of teachers who participated in a PD program that integrates science content deepening with analysis of practice. The comparison group participated in a PD program of equal duration and intensity, but only included content deepening. During a summer institute, teachers were given six lessons and then asked to teach the lessons in the fall. At the institute, the treatment group worked collaboratively to discuss video analysis of experienced science teachers with university faculty guided their thinking on targeted science ideas. During the fall, teachers taught the lessons from the institute. During their monthly sessions, they analyzed each other's teachings of those lessons and student work. During the spring, the group sessions shifted to developing their own lesson plans using STeLLA strategies and lenses. Teachers planned a sequence of connected lessons. At the culminating session, teachers shared their analysis of teaching their own lessons. During the summer institute, the comparison group participated in hands-on investigations, creation and analysis of content representations, science notebook writing, large and small group discussions, short lectures and readings, and field trips. During the school year, teachers taught targeted content from the summer institute. Both groups completed a total of 88.5 hours of PD.	**Methodology:** Cluster randomized controlled trial • *n*=144 4th– to 6th-grade teachers in 77 Colorado Front Range elementary schools and 2,823 students • Students' content knowledge, as measured by a project-specific test. **Findings:** Students of teachers participating in STeLLA outperformed students whose teachers did not participate (ES=0.52 standard deviations).
Wenglinsky, H. (2000). *How teaching matters: Bringing the classroom back into discussions of teacher quality.* Princeton, NJ: Educational Testing Service. **Description:** Researchers analyzed 1996 NAEP mathematics and science data for 8th-graders to investigate, among other questions, what aspects of teacher professional development result in increased student achievement.	**Methodology:** One-year descriptive survey analysis • *n*=7,146 8th graders for mathematics and 7,776 8th graders for science. • Student achievement measured using the 1996 National Assessment of Educational Progress (NAEP) **Findings:** In mathematics, students of teachers who participated in PD for teaching diverse students were 107% of a grade level ahead of their peers in math. Students whose teachers participated in PD in higher-order thinking skills were 40% of a grade level ahead of their peers. In Science, PD in laboratory skills was associated with students being 44% of a grade level ahead, compared to students with teachers who did not have this PD. However, PD in classroom management was associated with 37% of a grade level behind their peers for science, raising questions about the nature of the PD offered.

Appendix C:
Elements of Effective Professional Development by Study

Note: "NS" indicates not specified in study.

Seven Elements of Effective Professional Development

1. They are content focused.
2. They incorporate active learning strategies.
3. They engage teachers in collaboration.
4. They use models and/or modeling.
5. They provide coaching and expert support.
6. They include opportunities for feedback and reflection.
7. They are of sustained duration.

Study	Active Learning	Coaching/Expert Support	Collaborative	Content-Focused	Feedback	Reflection	Models/ Modeling	Sustained Duration
Allen, J. P., Pianta, R. C., Gregory, A., Mikami, A. Y., & Lun, J. (2011). *An interaction-based approach to enhancing secondary school instruction and student achievement.*	X	X	X		X	X	X	X
Allen, J.P., Hafen, C.A., Gregory, A.C., Mikami, A.Y. & Pianta, R. (2015). *Enhancing secondary school instruction and student achievement: Replication and extension of the My Teaching Partner-Secondary intervention.*	X	X	X		X	X	X	X
Antoniou, P. and Kyriakides, L. (2013). *A Dynamic Integrated Approach to teacher professional development: Impact and sustainability of the effects on improving teacher behavior and student outcomes.*	X	X	X	X	X	X	X	NS
Buczynski, S. & Hansen, C. B. (2010). *Impact of professional development on teacher practice; Uncovering connections.*	X	X	X	X	NS	X	X	X
Buysse, V., Castro, C.C., & Peisner-Feinberg (2010). *Effects of a professional development program on classroom practices and outcomes for Latino dual language learners.*	X	X	X	X	X	X	X	X
Campbell, P. F., & Malkus, N. N. (2011). *The impact of elementary mathematics coaches on student achievement.*	X	X	X	X	X	X	X	NS

Study	Active Learning	Coaching/Expert Support	Collaborative	Content-Focused	Feedback	Reflection	Models/ Modeling	Sustained Duration
Carpenter, T.P., Fennema, E., Peterson, P.L., Chiang, C., & Loef, M. (1989). *Using knowledge of children's mathematics thinking in classroom teaching: An experimental study.*	X	X	X	X	X	X	X	X
Doppelt, Y., Schunn C.D., Silk, E.M., Mehalik, M.M., Reynolds, B. & Ward, E. (2009). *Evaluating the impact of facilitated learning community approach to professional development on teacher practice and student achievement.*	X	X	X	X	X	X	X	X
Finkelstein, N., Hanson, T., Huang, C. W., Hirschman, B., & Huang, M. (2010). *Effects of problem based economics on high school economics instruction.*	X	X	X	X	X	X	X	X
Gallagher, H. A., Woodworth, K. R., & Arshan, N. L. (2015). *Impact of the National Writing Project's College-Ready Writers program in high-need rural districts.*	X	X	X	X	X	X	X	X
Gersten, R. Dimino, J., Jayanthi, M., Kim, J. S., & Santoro, L.E. (2010). *Teacher study group: Impact of the professional development model on reading instruction and student outcomes in first grade classrooms.*	X	X	X	X	X	X	X	X
Greenleaf, C. L., Hanson, T. L., Rosen, R., Boscardin, D. K., Herman, J., Schneider, S. A. (2011). *Integrating literacy and science in biology: Teaching and learning impacts of reading apprenticeship professional development.*	X	X	X	X	NS	X	X	X
Heller, J. I., Daehler, K. R., Wong, N., Shinohara, M., & Miratrix, L. W. (2012). *Differential effects of three professional development models on teacher knowledge and student achievement in elementary science.*	X	X	X	X	X	X	X	X
Johnson, C. C. & Fargo, J. D. (2014). *A study of the impact of transformative professional development on Hispanic student performance on state mandated assessments of science in elementary school.*	X	X	X	X	X	X	X	X

Study	Active Learning	Coaching/Expert Support	Collaborative	Content-Focused	Feedback	Reflection	Models/ Modeling	Sustained Duration
Johnson, C. C., & Fargo, J. D. (2010). *Urban school reform enabled by transformative professional development: Impact on teacher change and student learning of science.*	X	NS	X	X	X	X	X	X
Kim, J. S., Olson, C. B., Scarcella, R., Kramer, J., Pearson, M., van Dyk, D., Collins, P., & Land, R. E. (2011) *A randomized experiment of a cognitive strategies approach to text-based analytical writing for mainstreamed Latino English language learners in grades 6 to 12.*	X	X	X	X	NS	X	X	X
Kleickmann, T., Trobst, S., Jonen, A., Vehmeyer, J., & Moller, K. (2016). *The effects of expert scaffolding in elementary science professional development on teachers' beliefs and motivations, instructional practices, and student achievement.*	X	X	X	X	X	X	X	X
Kutaka, T. S., Smith, W. M., Albano, A. D., Edwards, C. P., Ren, L., Beattie, H. L., Lewis, W. J., Heaton, R, M., & Stroup, W. W. (2017). *Connecting teacher professional development and student mathematics achievement: A 4-year study of an elementary mathematics specialist program*.	X	NS	X	X	X	X	X	X
Landry, S. H., Swank, P. R., Smith, K.E., Assel, M. A., & Gunnewig, S. B. (2006). *Enhancing early literacy skills for preschool children: Bringing a professional development model to scale.*	X	X	X	X	X	X	X	X
Landry, S. H., Anthony, J. L., Swank, P. R., & Monseque-Bailey, P. (2009). *Effectiveness of comprehensive professional development for teachers of at-risk preschoolers.*	X	X	X	X	X	X	X	X
Lara-Alecio, R., Tong, F., Irby, B. J., Guerrero, C., Huerta, M., & Fan, Y. (2012). *The effect of an instructional intervention on middle school English learners' science and English reading achievement.*	X	X	X	X	NS	X	X	X
Marek, E. & Methven, S. B. (1991). *Effects of the learning cycle upon student and classroom teacher performance.*	X	NS	X	X	NS	X	X	X

Study	Active Learning	Coaching/Expert Support	Collaborative	Content-Focused	Feedback	Reflection	Models/ Modeling	Sustained Duration
May, H.; Sirinides, P. M., Gray, A., and Goldsworthy, H. (2016). *Reading Recovery: An evaluation of the four-Year i3 scale-up.*	X	X	X	X	X	X	X	X
McGill-Franzen, A., Allington, R. L., Yokoi, L., & Brooks, G. (1999). *Putting books in the classroom seems necessary but not sufficient.*	NS	NS	NS	X	NS	NS	X	X
Meissel, K., Parr, J. M., Timperley, H. S. (2016). *Can professional development of teachers reduce disparity in student achievement?*	X	X	X	X	X	X	X	NS
Meyers, C. V., Molefe, A., Brandt, W. C., Zhu, B., & Dhillon, S. (2016). *Impact Results of the eMINTS Professional Development Validation Study.*	X	X	X		X	X	X	X
Newman, D., Finney, P. B., Bell, S., Turner, H., Jaciw, A., Zacamy, J. L., & Gould, L. F. (2012). *Evaluation of the effectiveness of the Alabama Math, Science, and Technology Initiative (AMSTI).*	X	X	X	X	X	X	X	X
Penuel, W. R., Gallagher, L. P., & Moorthy, S. (2011). *Preparing teachers to design sequences of instruction in earth systems science: A comparison of three professional development programs*.	X	X	NS	X	NS	X	X	X
Polly, D., McGee, J., Wang, C., Martin, C., Lambert, R., & Pugalee, D.K. (2015). *Linking professional development, teacher outcomes, and student achievement: The case of a learner-centered mathematics program for elementary school teachers.*	X	X	X	X	NS	X	X	X
Powell, D. R., Diamond, K. E., Burchinal, M. R., & Koehler, M. J. (2010). *Effects of an early literacy professional development intervention on Head Start teachers and children.*	X	X	X	X	X	X	X	X
Roth, K. J., Garnier, H. E., Chen, C., Lemmens, M., Schwille, K., & Wickler, N. I. Z. (2011). *Video-based lesson analysis: Effective science PD for teacher and student learning.*	X	X	X	X	X	X	X	X

Study	Active Learning	Coaching/Expert Support	Collaborative	Content-Focused	Feedback	Reflection	Models/ Modeling	Sustained Duration
Sample McMeeking, L. B., Orsi, R., & Cobb, R. B. (2012). *Effects of a teacher professional development program on the mathematics achievement of middle school students.*	X	X	NS	X	NS	X	X	X
Saxe, G. B., Gearhart, M., & Nasir, N. S. (2001). *Enhancing students' understanding of mathematics: A study of three contrasting approaches to professional support.*	X	X	X	X	NS	X	X	X
Shaha, S. H. & Ellsworth, H. (2013). *Predictors of success for professional development: Linking student achievement to school and educator successes through on-demand, online professional learning.*	X		X	NS	NS	X	X	NS
Taylor, J. A., Roth, K., Wilson, C., Stuhlsatz, M, & Tipton, E. (2017). *The Effect of an Analysis-of-Practice, Videocase-Based, Teacher Professional Development Program on Elementary Students' Science Achievement.*	X	X	X	X	X	X	X	X
Total:	34 (1 NS)	30 (4 NS)	32 (3 NS)	31 (1 NS)	24 (11 NS)	34 (1 NS)	35	3 (4 NS)

Endnotes

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2. TNTP. (2015). *The mirage: Confronting the hard truth about our quest for teacher development.* Brooklyn, NY: TNTP.

3. Easton, L. B. (2008). From professional development to professional learning. *Phi Delta Kappan, 89*(10), 755–761; Fullan, M. (2007). *The new meaning of educational change, 4th edition.* New York City, NY: Teachers College, Columbia University.

4. Fullan, M. (2007). *The new meaning of educational change, 4th edition*, 35. New York City, NY: Teachers College, Columbia University.

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About the Authors

Linda Darling-Hammond is President of the Learning Policy Institute and Charles E. Ducommun Professor of Education Emeritus at Stanford University. She has conducted extensive research on issues of educator supply, demand, and quality. Among her award-winning publications in this area are *What Matters Most: Teaching for America's Future*; *Teaching as the Learning Profession*; *Powerful Teacher Education*; and *Preparing Teachers for a Changing World: What Teachers Should Learn and Be Able to Do.*

Maria E. Hyler is the Deputy Director of the the Learning Policy Institute's Washington, DC, Office and a Senior Researcher on LPI's Educator Quality and Deeper Learning teams. She is a co-author of *The Teacher Residency: An Innovative Model for Preparing Teachers* and is co-lead of a forthcoming study on teacher preparation for deeper learning. Her work focuses on structures and systems that support student success, best practices for preparing teachers to teach students of diverse backgrounds, and preparing equity-centered educators.

Madelyn Gardner is a Research and Policy Associate. She is a member of LPI's Early Childhood Education Team and is one of the co-authors of *The Road to High-Quality Early Learning: Lessons from the States.* Previously she worked at the Next Generation think tank where she focused on early childhood education and work-family policy in support of evidence-based policy development in California.

Danny Espinoza is a Research Assistant on the Educator Quality and the Equitable Resources and Access teams. He is a co-author of *Supporting principals' learning: Key features of effective programs.* As an undergraduate, he worked as a research assistant for the Institute for Latino Studies, assisting in studies exploring political identity formation for multiethnic voters. He also conducted research analyzing the impact and effectiveness of Chile's national education voucher program, particularly for students of low socioeconomic background.

LEARNING POLICY INSTITUTE

1530 Page Mill Road, Suite 200
Palo Alto, CA 94304
p: 650.332.9797

1301 Connecticut Avenue NW, Suite 500
Washington, DC 20036
p: 202.830.0079
@LPI_Learning | learningpolicyinstitute.org

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