Rigorous Project-Based Learning
An Inquiry-Based Educational Approach

Key Principles for Project-Based Learning

Lucas Education Research
GEORGE LUCAS EDUCATIONAL FOUNDATION

Research confirms that rigorous project-based learning has a positive impact on students, leading to increased achievement and higher levels of motivation.

Contents

What is rigorous project-based learning?

Project-based learning (PBL) is an inquiry-based educational approach in which students explore real-world problems through individual and group projects. This teaching and learning method encourages students to make sense of why content is useful and how it might be applied. Projects involve complex tasks organized around a challenging central question, resulting in reflection, iteration, and the creation of a final public product. The projects are anchored in core subject-matter content, allowing students to build knowledge in those important areas and develop strong problem-solving, critical-thinking, and collaboration skills. When integrated into the school day, PBL can be deeply engaging and effective as compared with traditional, teacher-centered instructional approaches. No single education lever can transform our education system, but PBL is a tool that can create a more student-centered learning environment that improves outcomes.

Research confirms that rigorous project-based learning has a positive impact on students, leading to increased achievement and higher levels of motivation (Larmer et al., 2015). Recent studies, discussed in greater detail below, have found that PBL is connected to learning gains in an array of academic subjects.

In a broad review of published research, MDRC, a social-policy research organization, highlighted numerous studies finding positive associations between PBL and students' development of knowledge and cognitive skills (Condliffe et al., 2017). The MDRC review pointed to findings from the American Institutes for Research that showed higher scores on the OECD PISA-Based Test for Schools, an international academic assessment given to 15-year-olds, and higher on-time high school graduation rates in schools that were part of the deeper learning network as compared with schools that taught with more-traditional instructional practices. The network schools in the study were part of the William and Flora Hewlett Foundation's deeper learning community of practice and used project-based learning (Zeiser et al., 2016).

A recent meta-analysis of PBL research, looking at journal articles published over a 20-year period, found project-based learning had a medium to large positive effect on students' academic achievement compared with traditional instruction (Chen & Yang, 2019). And in a study in four countries in South and Central America, researchers reported that inquiry and problem-based learning improved students' math and science scores on standardized tests (Bando et al., 2018).

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As with many educational efforts, however, not all PBL is equal. The MDRC review found what an earlier landscape analysis stated—that the field hadn't come together around clear PBL design principles and further research was needed. Lucas Education Research (LER), a division of the George Lucas Educational Foundation (GLEF), has been supporting independent research studies to help identify what generates rigorous and effective PBL and what drives learning gains and other positive student outcomes. The studies have produced evidence of what works, and LER continues to invest in gold-standard research that can yield further insights and help improve teaching and learning. PBL practice should not be isolated from research. Doing it well requires a commitment to evidence-based practices. Recent research findings support a set of project-based learning design principles that ensure PBL is rigorous and will benefit students. This report, an update on a 2015 paper, outlines those design principles and lays out the latest and most robust research underpinning them.

Developing an evidence-based, shared understanding of what constitutes rigorous PBL can help alleviate challenges in designing and implementing projects. While teachers overwhelmingly support PBL, they often identify obstacles to using it with their students. For example, in a survey of AP U.S. Government and Politics and AP Environmental Science teachers, 70 percent reported that it was hard to find well-designed projects aligned to course content (Lucas Education Research, 2015). The majority of those same teachers said that using PBL with their students would have a positive impact on student learning. Teachers reported that obstacles to implementing PBL included a lack of access to resources; a lack of planning and instructional time; and the need for meaningful, sustained professional learning.

4 KEY DESIGN PRINCIPLES

Identifying core design principles of rigorous PBL can inform instruction, curriculum development, and professional learning and promote equitable opportunities for learning. The four key design principles detailed in this report underpin good PBL instruction, and the research is clear that project-based learning must incorporate the following:

1. Purposeful and authentic experiences
Effective PBL requires purposeful and authentic experiences generated by students engaging in relevant questions. A main question should drive a unit of study, and that question should be feasible to consider, worthwhile, contextualized, meaningful, and ethical (Krajcik & Shin, 2014).

These questions should be related to students' lives, the communities in which young people reside, and real-world issues happening outside the classroom. For example, projects might address questions such as how to design a new park that supports local plant life, build affordable housing, or solve a public-health problem. Projects should be coherently sequenced and use tools, practices, and standards relied upon in real-world settings.

2. Deep integration with course content
Projects should feature deep integration with course content and be rooted in core subject areas, helping to deepen and build student knowledge of important topics. The multi-dimensional nature of PBL makes it a strong approach for interdisciplinary learning, so projects can simultaneously build student understanding of math concepts, scientific phenomenon, and improve literacy skills, for example.

3. Meaningful and supportive relationships
Meaningful and supportive relationships matter in education generally and definitely with project-based learning. Schools with a strong culture of collaboration and that reward risk taking, view mistakes as learning opportunities, and emphasize students' social and emotional learning skills foster rich PBL environments. Quality PBL benefits from collaborative peer-to-peer interactions and trusting student-teacher relationships.

4. Evidence-based teaching and assessment practices
Learning from research and relying on evidence about what works is essential. This report looks at PBL-related studies and highlights evidence-based teaching and assessment practices that can have a positive effect on student outcomes. Some of these practices include providing feedback to students in a strategic and timely manner, creating opportunities for reflection, and empowering students to share their learning with others. There is still much to learn, but research has led to a lot of information about the practices that benefit PBL instruction. When educators are supported in using these approaches—through professional-learning opportunities, collaborative teaching environments, and quality resources—they can feel confident in their ability to bring rigorous PBL into their classrooms.

This paper describes each design principle, as well as the supporting research, in further detail below. Taken together, these four design principles provide a framework for how to develop, execute, and scale project-based learning that can transform education in the United States and globally.

1 Purposeful and authentic experiences

1. Purposeful and authentic experiences

Rigorous PBL should be purposeful and consist of a coherent set of experiences that are strategically sequenced. With strong PBL instruction, students revisit concepts and skills through projects over time, deepening knowledge and strengthening skills. "They are not sporadic activities or culminating activities that come at the end of an instructional sequence, nor are they lively interludes inserted periodically into traditional recitation" (Parker & Lo, 2015, p. 4).

When designed and implemented in this manner, project-based learning works. Consider the Knowledge in Action (KIA) Project, developed by researchers at the University of Washington and high school teachers. They redesigned Advanced Placement courses to weave five to seven projects into the classes. Students investigate content in a looped fashion through multiple scenarios, which gives them a chance to revisit ideas and practice important skills. For example, in an AP Environmental Science course, students examine the question of living more sustainably through a project looking at their own ecological footprint as well as projects exploring global and community issues.

A randomized controlled study designed to determine the efficacy of KIA in five large school districts looked at the impact of project-based learning on students' AP U.S. Government and Politics and AP Environmental Science exam scores. The study found KIA increased the likelihood of earning a score of 3 or higher on the AP exam by 8 percentage points. A follow-up study showed when teachers had two years of experience using KIA, students had a 10-percentage-point boost in the probability of earning an AP Exam score of 3 or higher with KIA.

Projects should also be authentic to students, their communities, and the larger world around them, including the workforce. Students need choice and agency, the opportunity to address audiences through public performances and products, and access to and instruction on the use of authentic tools that people use in contemporary life outside of school (Polman et al., 2018). An example of a tool that might be used in an English class is video-editing software to create digital videos. An example in a science class might be software that allows for data analysis and visualization.

By making instruction explicitly connected to outside-the-classroom practices, projects can promote a sense of civic purpose and engagement, which can be especially powerful when projects result in genuine products or performances for an authentic audience. This is consistent with research demonstrating that students learn most effectively when learning takes place in authentic contexts (National Academies of Sciences, Engineering, and Medicine, 2018).

In the KIA project, for example, simulations rooted in actual historic events, as well as current-day activities, help students with perspective-taking and applying what they know and can do to solving problems. In the AP U.S. Government and Politics course, students take on the role of delegates to the Constitutional Convention of 1787, deciding whether to ratify the new U.S. Constitution. They also organize and execute their own modern-day presidential campaign, write legislation in Congress, serve as advisors to interest groups, and create political action plans.

AP Physics teacher Johnny Devine of Tacoma, Washington, said students find it meaningful to engage in projects that put them in the shoes of someone in the workforce, such as a NASA systems engineer designing a Mars lander. "When they see there is this interesting problem that is being tackled out there and that is a thing that can lead to an actual job for them, they're much more motivated to look at the physics behind it," Devine explained.

To ensure project-based learning is authentic to students, it should include culturally relevant practices. University of Wisconsin researcher Emily Miller relayed that curricular resources should connect projects to students' lives and experiences through prompts and by pulling in other resources as needed to help students connect to the work at hand. Miller is a researcher on the Multiple Literacies in Project-Based Learning Project, which is discussed in greater detail below and which examines the effects of PBL on science learning. For example, in designing a garden to grow food in their own community, students in the Detroit area watch and discuss a video featuring Ron Finley, who transformed an urban community not unlike theirs through community gardening. And during a project in which they design toys, the students learn about Lonnie Johnson, a Black engineer who invented the Super Soaker and who created many iterations of the best-selling water toy before landing on the ultimate design.

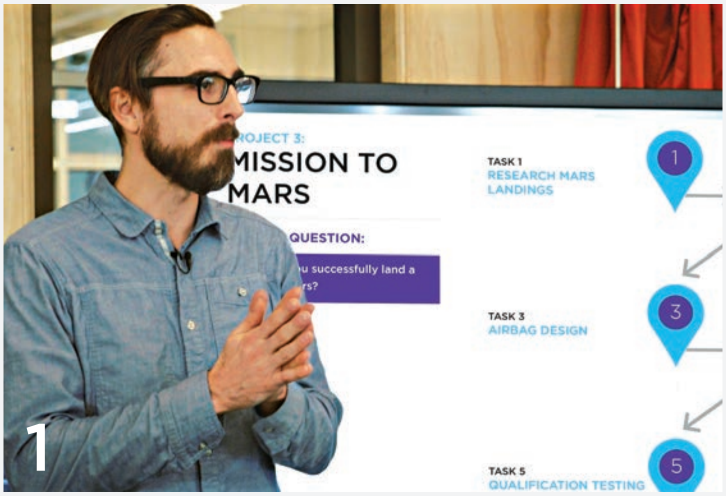
Ensuring projects are relevant, authentic, and meaningful to students in this manner enhances the rigor of PBL, deepens student engagement, and increases the likelihood of achievement gains.

KNOWLEDGE IN ACTION

Designing a Mars Lander

Johnny Devine, a Knowledge in Action AP Physics teacher, engages students in a project that answers the question, “How can you successfully land a rover on Mars?”

(VIDEO)



Students take on the role of NASA engineers in charge of the entry, descent, and landing of a Mars rover. They are tasked with designing and testing a model of the lander structure on the Mars rover.

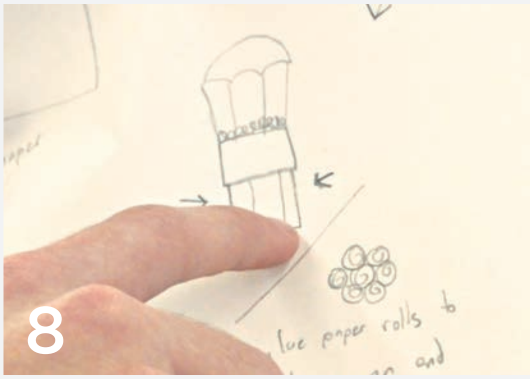
Students develop understanding of core physics concepts, including air resistance and velocity, as they prototype the parachute of the lander. The iterations of testing promote deep engagement in physics practices.

Designing a Mars Lander

continued

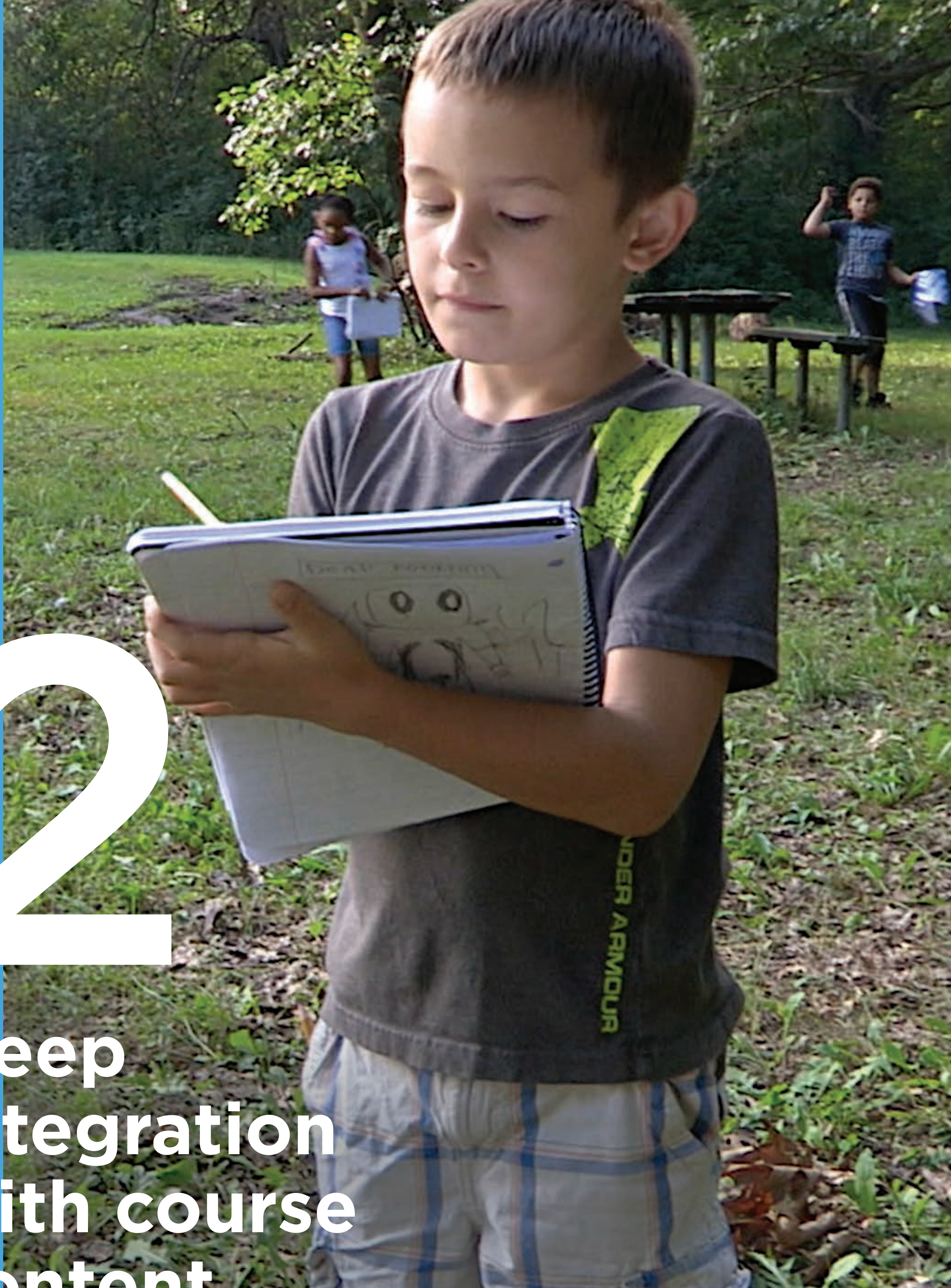
(VIDEO)

Students create a design report similar to one prepared for real Mars missions by actual NASA engineers. They collect evidence from their testing of the landers' air bags to support their design choices.



Students consider concepts of energy and go deeper on topics introduced in prior units. They use their developing understanding of physics to recommend a design for the heat shield of the lander.

Real engineers visit the classroom to provide feedback to the students about their designs. The project culminates with students performing the final test with their complete lander design.



2

Deep integration with course content

2. Deep integration with course content

Research highlights the need for projects to target specific learning goals, promote the development of content knowledge, and provide experiences through which students learn disciplinary skills (Condliffe et al., 2017; Thomas, 2000). Projects can deepen knowledge in individual subject areas and help students understand how to apply what they learn in core subjects—such as math, science, and English language arts—to addressing issues in the world beyond school. Integrating this knowledge-in-use approach in the classroom not only provides a richer experience but also can motivate student interest in learning (Blumenfeld et al., 1991; Krajcik & Czerniak, 2013).

In addition to deepening knowledge in a single, specific content area, PBL can also provide an opportunity to combine content and skills across subject areas. This can help prepare students for interdisciplinary applications of what they learn in school later in life.

For example, the Multiple Literacies in Project-Based Learning (ML-PBL) project, developed by researchers at Michigan State University and the University of Michigan, focuses primarily on science, but it also provides elementary school students with opportunities to engage in purposeful reading, explanatory writing, and mathematics (Miller & Krajcik, 2019). "Multiple Literacies in Project-Based Learning is all about trying to support children really learning science to a level that they can use their knowledge. But in order to support them in using that knowledge, we also engage them in literacy and in learning mathematics," explained Joseph Krajcik, professor of science education at Michigan State and the lead researcher on the study.

As described earlier, teaching and learning in the ML-PBL curriculum center around driving questions such as, "How can we plan gardens for our community to grow plants for food?" and "How can we design fun moving toys that other kids can build?" This type of purposeful, authentic inquiry allows students to learn content and new skills through dynamic experiences.

A study into the efficacy of the program found that third-grade students using the curriculum performed significantly better on an independently developed science assessment aligned with state content expectations than their peers receiving more-traditional instruction. All students using the ML-PBL curriculum, including struggling readers, outperformed the students in the control group. That is particularly notable since reading ability is highly correlated with success in other academic areas (O'Reilly & McNamara, 2007).

This study suggested that interdisciplinary PBL can be an effective way to bolster achievement in science for all students, regardless of socioeconomic status, gender, race, or reading performance. The average performance on an end-of-year science test for students in PBL classrooms was 10 percentage points higher than performance for students in the comparison group. Findings revealed that the positive effects of PBL on science learning also extended to social and emotional learning. Students exposed to the interdisciplinary approach to PBL frequently reported the value of taking ownership of their work, reflecting on their work, and collaborating.

Another study, led by University of Michigan literacy expert Nell K. Duke and Anne-Lise Halvorsen, a social studies education expert from Michigan State University, found positive effects when using an interdisciplinary approach to project-based learning. They found that second graders in high-poverty schools closed the gap with wealthier peers in social studies knowledge and informational reading skills when engaged in project-based learning that interwove social studies and literacy instruction through a program called Project PLACE: A Project Approach to Literacy and Civic Engagement (Halvorsen et al., 2012).

A follow-up study, which was a randomized controlled trial, revealed significant improvements for participating students in performance on measures of social studies knowledge and informational reading. In that study, PBL led to a gain in social studies achievement that was equivalent to five to six months of increased learning for the participating students over a comparison group and two months of increased learning in informational reading (Duke et al., 2020).

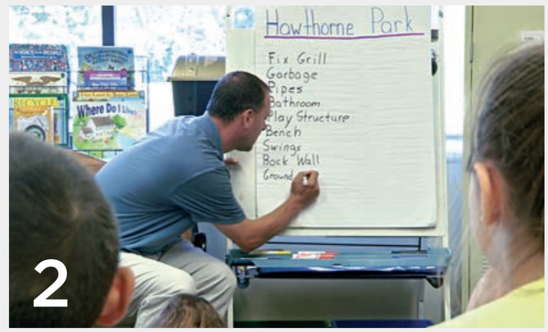
The Project PLACE program features highly engaging lessons. In an economics unit, the students develop flyers for a local business, using authentic tools and practices a local business owner might use, and create their own goods and services to sell for a cause. For a unit on civics and government, students develop proposals for local officials to consider for improving a local park or other public spaces.

PROJECT PLACE

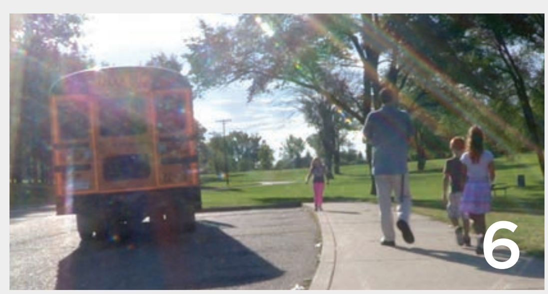
A Proposal to Improve a Local Park

Second-grade teacher Aaron Phillips begins a unit by taking his students on a field trip to observe a local park. During the unit, students learn about civics and government and develop writing and presentation skills. The goal is to create a proposal for a local official to improve the park for the community.

(VIDEO)



Students discuss their observations and identify problems at the park that they want to help solve. The class creates a survey to discover how their community feels about the problem.



Through reading and discussions, students learn about the purposes of government and responsibilities of citizens and civic leaders. They apply their learning to the problems they want to fix in the park.

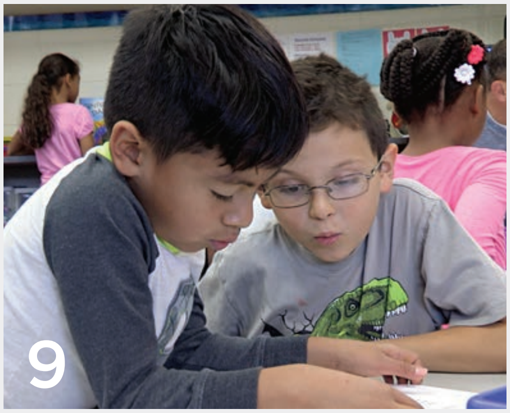
PROJECT PLACE

A Proposal to Improve a Local Park

(VIDEO)

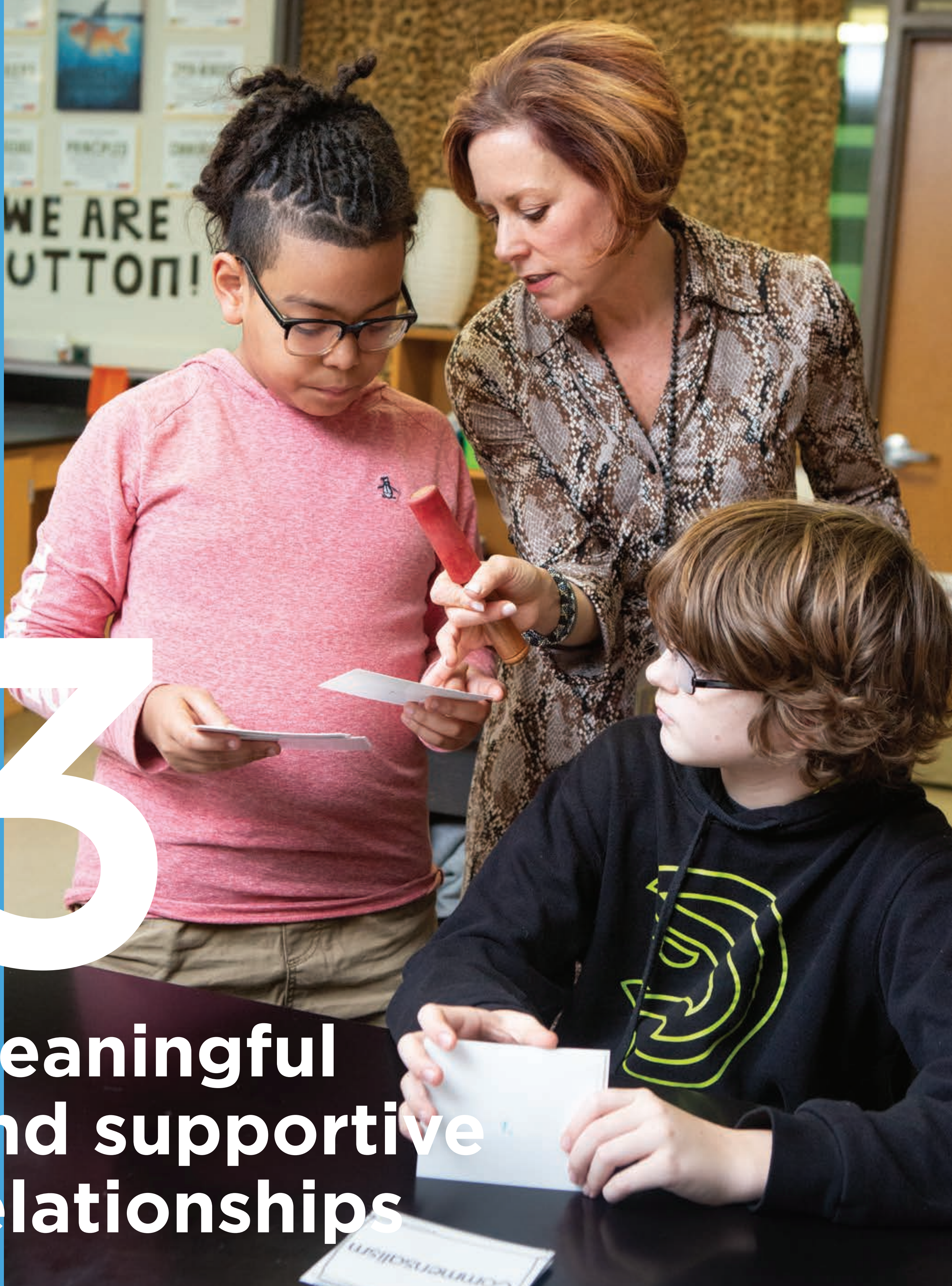
continued

Students use technology to learn what different local government departments are responsible for and work collaboratively to present their ideas to the class.



Students write a proposal to improve the park based on their survey data and what they have discovered about civics and government, gaining key writing skills.

Students create and deliver a persuasive public presentation to city councilman Randy Carter, demonstrating how they can have an impact on their community.



3

Meaningful and supportive relationships

3. Meaningful and supportive relationships

PBL benefits from the kind of strong school and classroom culture that puts students at the center of their learning, encourages them to work through challenging material and take intellectual risks, and makes meaningful collaboration the norm. These are learning environments where students are decision makers but where teachers guide students and facilitate project-based learning. As education researcher Linda Darling-Hammond (2008) stated, “Students should be encouraged to be authors and producers of knowledge” (p. 216). Creating this active learning environment, so central to rigorous PBL, requires positive teacher and student interactions and attention to students’ social and emotional learning skills.

Key components of social and emotional learning include the encouragement and development of students’ collaboration and communication skills. With effective PBL, students and teachers engage in collaborative activities to find solutions to driving questions that mirror skills and competencies that experts use in solving problems (Krajcik & Shin, 2014).

Teachers set norms and expectations for collaboration and dialogue, for example, ensuring all students participate equitably. And teachers work to establish methods of encouraging group and individual accountability for collaborative work. In Stanford University’s Learning Through Performance Project, which developed a **sixth-grade science curriculum** aligned with Next Generation Science Standards (NGSS), the first unit of the year requires group-based work and explicitly establishes group norms and expectations designed to increase student engagement. It relies on principles from an educational approach called Complex Instruction (Cohen & Lotan, 1997) and lets students practice applying productive strategies to group-based work while completing a collaborative launch project. This foundational unit sets the stage for subsequent units by supporting early establishment of collaborative skills.

In a **study** of a third-grade classroom using the ML-PBL curriculum, the classroom teacher was observed eliciting students’ ideas about what it means to work together and challenges they might face while doing so. The teacher also shared her ideas for engaging in productive collaboration with peers, including planning together, communicating, and comparing ideas (Fitzgerald, 2020).

Seattle high school history teacher Jerry Neufeld-Kaiser, who has used the Knowledge in Action AP U.S. Government and Politics curriculum, said that ensuring all voices are heard is central to PBL. He elaborated, “This project approach gives you a chance to engage the students who might otherwise sit and hide and keep a low profile and not do well. Projects make their performance clearer to see, and their success shows more clearly.”

Key components of social and emotional learning include the encouragement and development of students’ collaboration and communication skills. With effective PBL, students and teachers engage in collaborative activities to find solutions to driving questions.

In an American Institutes for Research study examining schools successfully using project-based learning, educators emphasized interpersonal skills. In the majority of those schools, group-based work occurred on a daily basis, and assessment strategies, such as portfolios and presentations, included both content knowledge and communication and collaboration skills. In addition, peer review and peer feedback were critical to the portfolio process in several of the schools (Huberman et al., 2014).

Researchers at the University of Colorado at Boulder developed and studied **Compose Our World**, a project-based approach to ninth-grade English language arts that emphasizes social and emotional learning. Students in these classrooms reported more collaboration and more authentic learning experiences than students in comparison classrooms, and teachers associated the course with positive instructional shifts and stronger English language arts teaching (Boardman et al., 2020). A qualitative study of a subset of those classrooms showed that everyday forms of care for one another influenced the experiences of students and teachers, and these were shaped by how space was used in classrooms, project requirements set by teachers, and the materials and modes students used to author products (Garcia et al., 2020).

MULTIPLE LITERACIES IN PROJECT-BASED LEARNING

Designing Toys That Move

Third-grade teacher Stacey Hodkiewicz introduces her students to a unit about toys. She solicits student responses to the driving question, "How can we design fun moving toys that other kids can build?"

(VIDEO)

Students draw upon their funds of knowledge and prior experiences to consider the question and make predictions about the pattern of motion of ready-made toys.

Groups of students work together to design, build, and revise their chosen type of toy. During this process, students learn the core ideas of force, motion, and engineering design.

Designing Toys That Move

(VIDEO)

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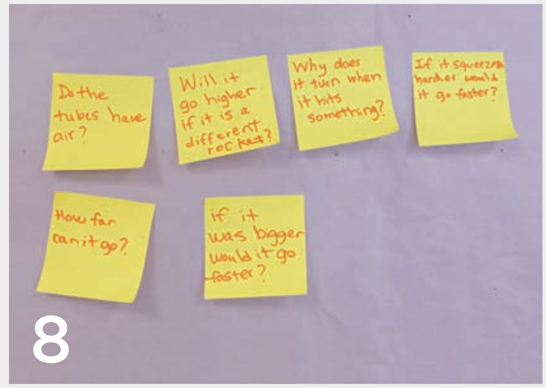
Ms. Hodkiewicz offers students multiple chances to share and discuss their ideas. Structured discourse allows students to make sense of the science phenomenon they are investigating.



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Students draw models as a way to explain their understanding with opportunities to revise, reflect, and peer-review these models. The teacher evaluates the student models as formative assessment for the unit.

11

Students consider how forces affect their toy design and its acceleration. They gain evidence to support their scientific claims and then present a final model of their toys.

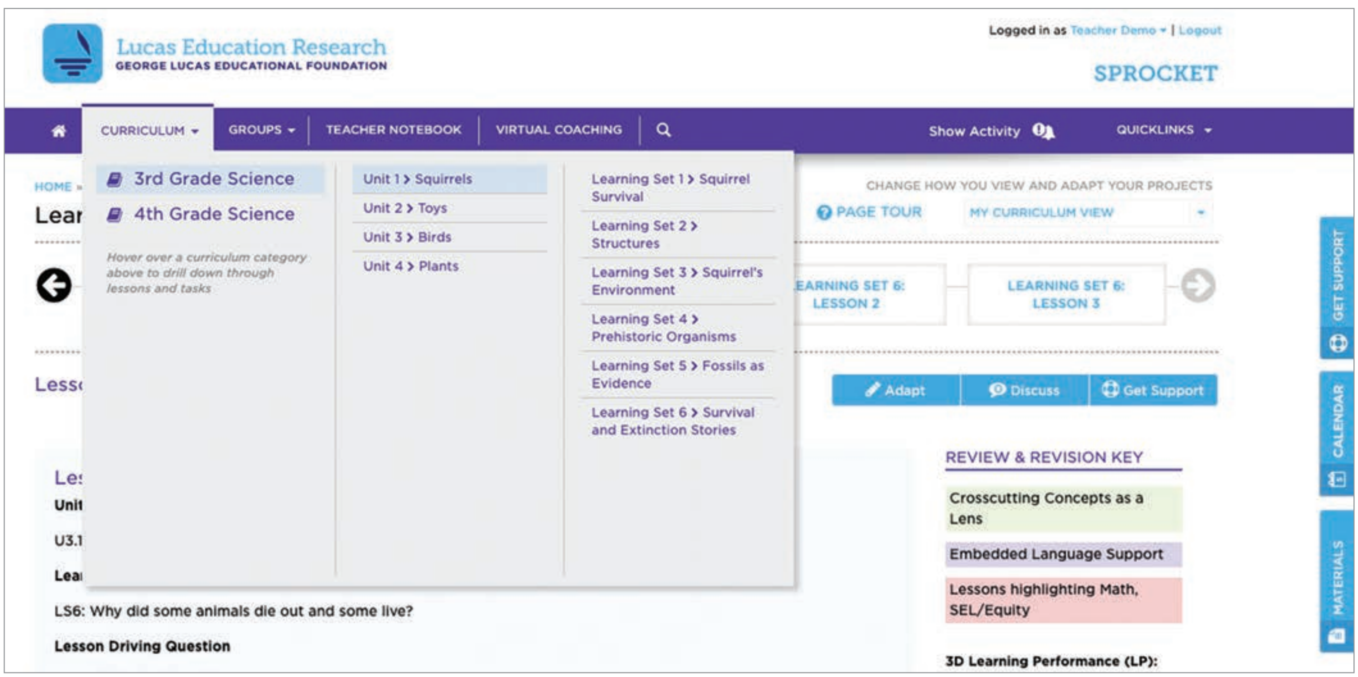
12

In an observation of the Project PLACE program geared to second graders in Michigan, teachers were seen encouraging meaningful student-to-student conversations and empowering the children to work in groups and come up with and present shared ideas to improve an area park and playground.

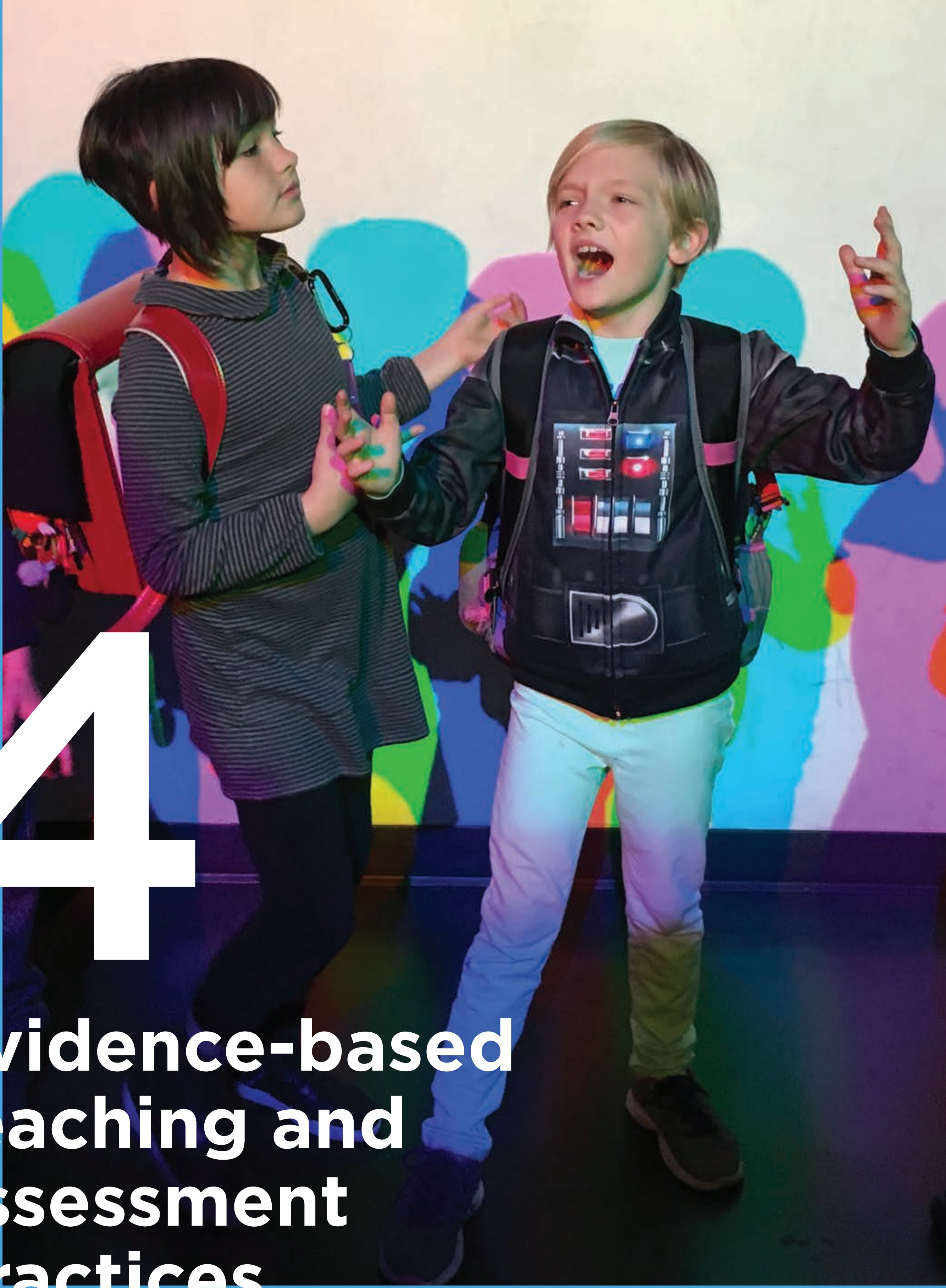
Other components of social and emotional learning that help make PBL successful include the development of empathy in students and the ability to consider other people's perspectives. For instance, in one ML-PBL classroom, students were observed engaging in lively and respectful conversations about earthquakes. One child shared that her mother had lived through a major earthquake in Mexico. She described to her peers the sadness her mother had felt seeing her childhood home destroyed, and her peers asked empathetic and relevant questions, demonstrating the caring and compassionate dialogue expected in a classroom using strong PBL instruction.

Family engagement is also critical, and community knowledge can be tapped to strengthen academic experiences. Families and larger communities are important contexts and contain interconnected networks where learning occurs, and classroom learning is enhanced when there is space to develop and exchange diverse "funds of knowledge" (Gonzalez et al., 2001).

The Sprocket Platform



The Sprocket platform allows researchers to share PBL curriculum with teachers. Teachers can use Sprocket to navigate the units of the ML-PBL Curriculum, shown here. The tool highlights disciplinary standards and key ideas of social and emotional learning to support teachers with instruction and relationship building. The platform also allows teachers to share adaptations they make with other teachers, allowing for peer collaboration.



4 Evidence-based teaching and assessment practices

Photo: Brightworks

4. Evidence-based teaching and assessment practices

It's critical for educators trying PBL to have evidence from the field about what works. A team of researchers at the University of Pennsylvania examining the teaching practices of experienced PBL teachers is supporting that goal.

In their observations of teachers using PBL, the researchers found that strong, evidence-based PBL instructional practices must be anchored in core academic disciplines. They noted that teachers who designed projects with their class often started with content standards and built projects around them. At other times, teachers started with a project idea and then considered what content areas they wanted to teach and assess.

In addition, University of Pennsylvania's Pam Grossman and her colleagues, who are studying PBL practices, reported, "Accomplished PBL teachers don't just assign projects for projects' sake" (Grossman et al., 2019, p. 3). Teachers designed projects to elicit critical thinking and encourage students to engage with disciplinary content and practices. For example, in a science class where rigorous PBL is the norm, teachers might ensure students use scientific methods to explore key questions specific to a scientific discipline. Similarly, in a history class using high-quality PBL, teachers might ask students to read and evaluate the reliability of primary sources and corroborate them with other primary and secondary sources, just as historians do when investigating a topic.

Grossman and her colleagues also related that authenticity is central to rigorous PBL. They observed that experienced teachers drew out students' positions and perspectives on topics and encouraged them to connect their ideas and work to the world beyond the classroom. That can be done through project design and by reminding students of the intended audience and purpose for their work. For example, if a project's topic is likely to be new to the audience, a teacher might help students provide enough background information so the audience can access the information the students want to share.

Projects should also include ongoing peer and teacher feedback through which teachers create opportunities for reflection and revision (Hammond, 2008). Teachers who excel in PBL track student progress and provide feedback that is both timely and meaningful and ask probing questions to help students improve their work. In addition, teachers support students as they define roles, manage group processes, and reflect on and refine their collaborative efforts. The University of Pennsylvania researchers observed that establishing group collaborative norms and working agreements is helpful.

Rigorous PBL also requires instruction to be informed by evidence of student learning. Students develop understanding when they produce work and revise artifacts guided by feedback. Good projects offer multiple and varied ways for students to demonstrate understanding. Project artifacts, performance-based artifacts, and diagnostic and conceptual assessments all can serve a purpose in PBL. To ensure inclusivity, learning opportunities and tasks should be universally designed to stimulate interest and motivation and provide differentiated ways for all students to express what they know (Meyer et al., 2014).

High-quality PBL depends on teachers using formative assessments both to drive student learning and in self-reflective ways to inform and improve their own instruction. In PBL, strategically integrated assessments can provide a rich understanding of the student learning that takes place over time.

In Stanford University's Learning Through Performance Project, science assessment experts partnered with middle school science teachers to develop and pilot a yearlong **sixth-grade science curriculum** based on scientific phenomena and aligned with Next Generation Science Standards. Each PBL unit includes integrated performance-based assessments that evaluate individual as well as group performance. After students completed the course, researchers found students outperformed a comparison group on a science assessment that measured students' proficiencies with Next Generation Science Standards practices. They also showed higher levels of engagement and significantly higher achievement on both the English language arts and math state tests as compared with a matched sample of students who did not complete the course. Additionally, English language learners did significantly better on the state English language proficiency test than a matched sample (Holthuis et al., 2018).

Learning Through Performance provides teachers and students with clear expectations for performance outcomes, student products, and rubrics to evaluate learning. In doing so, PBL is woven throughout a unit that introduces students to the phenomena to be studied and the project to be completed. Through each lesson within the unit, students learn new content related to the phenomena and driving questions, which allows them to acquire a deeper understanding of the content and the ability to apply their knowledge to complete the project.

The integration of the project throughout the learning process fosters group and individual accountability and encourages students to create products that provide teachers with evidence of their learning. Individual science tasks build up to a culminating project. For example, in a unit on the thermal dynamics of heat transfer, students design, build, and test a device that measures the way that thermal energy transfers between and within systems. During each task, students use a project organizer to capture pieces of evidence that will inform their final project and serve as formative assessments. This allows teachers to monitor students' progress and address content misunderstandings.

In a follow-up phase of research, Stanford researchers partnered with San Francisco Unified School District teachers and leaders to consider how to best support teachers in using NGSS-aligned PBL curriculum and evidence-based instructional practices in their classrooms. They developed a comprehensive model of professional learning that includes the training of site-based teacher-leaders. When educators have the opportunity to engage in professional-learning communities and share samples of student work and videos of teaching and learning, they can discuss students' understanding of key concepts and share instructional practices with other teachers.

PBL is most viable when it features this kind of high-quality and sustained professional learning. In the American Institutes of Research study, school administrators and teachers interviewed cited teacher collaboration and professional community as important to facilitating their ability to teach PBL (Huberman et al., 2016).

Rubric to Assess Science Content Learning Through Student Projects

The student demonstrates scientific knowledge of the following content standards	Emerging	Developing	Proficient	Advanced
A solution needs to be tested and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem (ETS1.B)	Constructs an explanation about how the device was modified based on no investigation data and/or with major errors	Constructs an explanation about how the device was modified based on limited investigation data and/or with minor errors	Constructs an accurate explanation about how the device was modified based on investigation data	Constructs an accurate and detailed explanation about how the device was modified based on investigation data
Energy is spontaneously transferred out of hotter regions or objects and into colder ones (MS-PS3-3.B)	Constructs an explanation about energy transfer with no evidence and/or major errors	Constructs an explanation about energy transfer with limited evidence and/or minor errors	Constructs an accurate explanation about energy transfer with evidence	Constructs a detailed accurate explanation about energy transfer with evidence

Learning Through Performance provides teachers with rubrics to evaluate the final performance assessment of student projects. This rubric, from a unit in which sixth-grade students write a patent application for a device they design that maximizes or minimizes thermal energy transfer, is given to students at the beginning of the unit, which provides clear expectations that students should be able to accomplish in the final product aligned to the Disciplinary Core Ideas from the Next Generation Science Standards. The Disciplinary Core Ideas in the chart above are reproduced verbatim from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* by the National Research Council.

LEARNING THROUGH PERFORMANCE

Constructing a Thermal Device

Sixth-grade teacher Taji Allen-Sanchez leads students in figuring out, "How can we design a device to warm something up?"

(VIDEO)

In this project, students take on the role of engineers and are tasked with designing and testing a device that maximizes or minimizes thermal energy transfer.

Students work together to investigate and make sense of the science ideas needed as they work to design their device. Teachers assess student progress throughout their design.

Constructing a Thermal Device

(VIDEO)

continued

At a professional-learning session, teachers discuss various approaches to using evidence-based practices and performance assessments in their classrooms.

The course scaffolds how students work as a group and sets explicit "group work" norms and roles that are used throughout the project.

Students work collaboratively on a group design of the device, experiencing an authentic engineering design process. Individually, each student writes a patent application for the device showcasing understanding of science ideas.

Summary

The research supporting PBL as an instructional approach that can improve student outcomes is strong and growing. LER is committed to ongoing research efforts aimed at providing further insights into how to design and implement PBL effectively.

The four design principles highlighted in this report are rooted in rigorous research. LER and its partners have learned that using them leads to positive change in classrooms and schools. We hope that by sharing them here, and updating the evidence base underpinning them, we can support the field, both in terms of curriculum design and the implementation of PBL.

It is clear that rigorous PBL has to be purposeful and authentic, driven by a focus on and the integration of course content, enhanced by meaningful and supportive interactions, and implemented using evidence-informed teaching and assessment practices. With a focus on equitable outcomes for all students, each pillar of this framework is critical for PBL to create learning environments that enable students to produce their best work that connects important disciplinary content to the world around them.

In summary, recent **research findings** examining the impact of PBL reveal statistically significant, positive, and robust effects on student achievement across disciplines and grade levels. Examples include the following: An early elementary school curriculum led to a 63 percent gain in social studies knowledge and a 23 percent gain in informational reading skills. A curriculum for older elementary school students led to an 8-percentage point gain on a third-party measure of science achievement and significant, positive shifts in students' collaborative skills and reflection. An NGSS-aligned PBL curriculum that integrates performance-based assessments improved student engagement and achievement on state tests, including substantial improvements in language proficiency for English learners. Students using project-based learning in AP courses significantly outperformed other students with an overall 10 percent increase in pass rates.

Ongoing research supported by LER will further inform the field. These include studies that are looking at PBL as it relates to effective instructional practices, quality professional learning, and systems change.

The efforts described herein draw on research-practitioner partnerships, and LER is grateful to the many teachers who have worked to innovate and try promising practices to improve teaching and learning and to researchers who are committed to finding and presenting evidence of what works. Such evidence will help further crystalize what rigorous PBL looks like and how to scale it so we can ensure all students engage in powerful learning, are creative problem solvers and collaborators, and can apply what they know and can do to the world around them.

Finding interdisciplinary PBL resources for the classroom can be challenging for teachers. As a result, most design and implement PBL on their own (Condliffe et al., 2017). One open and freely available educational resource is **Sprocket**, an online tool available through Lucas Education Research. The Multiple Literacies in PBL and Knowledge in Action resources described above can be found on Sprocket. These courses are aligned with the Next Generation Science Standards and College Board's AP frameworks. Teachers are encouraged to adapt the materials for their classrooms. The site also serves as a platform for professional learning and collaboration. Teachers can also find PBL resources on **Edutopia**, a website published by the George Lucas Educational Foundation.

ACKNOWLEDGMENTS

This paper was originally produced by AnnMarie Baines and Angela DeBarger with contributions from Kristin De Vivo, Nathan Warner, Sheree Santos, and Jordan Brinkman.

This updated version was produced with contributions from Kristin De Vivo, Denis Udall, Nancy Zuckerbrod, Kate Felsen, and Rochelle Urban.

LER grantees provided additional guidance with the writing and reviewing of the paper. They include Alison Boardman of the University of Colorado, Nell Duke of the University of Michigan, Miranda Fitzgerald of the University of North Carolina, Pam Grossman of the University of Pennsylvania, Anne-Lise Halvorsen of Michigan State University, Joseph Krajcik of Michigan State University, Emily Miller of the University of Wisconsin, Annemarie Palincsar of the University of Michigan, Joseph Polman of the University of Colorado, and Christopher Pupik Dean of the University of Pennsylvania.

REFERENCES

Bando, R., Näslund-Hadley, E., & Gertier, P. (2018). *Inquiry and problem-based pedagogy: Evidence from 10 field experiments*. Inter-American Development Bank.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist, 26*(3–4), 369–398.

Boardman, A. G., Garcia, A., Dalton, B., & Polman, J. L. (2020). *Compose our world: Project-based learning in secondary English language arts*. Teachers College Press.

Darling-Hammond, L., Barron, B., Pearson, P. D., Schoenfeld, A. H., Stage, E. K., & Zimmerman, T. (2008). *Powerful learning: What we know about teaching for understanding*. John Wiley and Sons, Inc.

Chen, C. H., & Yang, Y. C. (2019). Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators. *Educational Research Review, 26*(1), 71–81.

Cohen, E. G., & Lotan, R. A. (1997). *Working for equity in heterogeneous classrooms: Sociological theory in practice*. Teachers College Press.

Condliffe, B., Quint, J., Visher, M., Bangser, M., Drohojowska, S., Saco, L., & Nelson, E. (2017). *Project-based learning: A literature review*. MDRC.

Duke, N. K., Halvorsen, A., Strachan, S. L., Kim, J., & Konstantopoulous, S. (2020). Putting PjBL to the test: The impact of project-based learning on second graders' social studies and literacy learning and motivation in low-SES school settings. *American Educational Research Journal*.

Fitzgerald, M. (2020). Overlapping opportunities for social-emotional and literacy learning in elementary-grade project-based instruction. *American Journal of Education*.

Garcia, A., Guggenheim, A., Stamatis, K., & Dalton, B. (2020). Glimmers of care: Attending to the affective everyday in ninth-grade literacy classrooms. *Reading Research Quarterly*.

Gonzalez, N., Andrade, R., Civil, M., & Moll, L. (2001). Bridging funds of distributed knowledge: Creating zones of practices in mathematics. *Journal of Education for Students Placed at Risk, 6*(1–2), 115–132.

Grossman, P., Pupik Dean, C. G., Schneider Kavanagh, S., & Hermann, Z. (2019). Preparing teachers for project-based teaching. *Phi Delta Kappan, 100*(7), 43–48.

Halvorsen, A., Duke, N. K., Brugar, K. A., Block, M. K., Strachan, S. L., Berka, M. B., & Brown, J. M. (2012). Narrowing the achievement gap in second-grade social studies and content area literacy: The promise of a project-based approach. *Theory and Research in Social Education, 40*(3), 198–229.

Holthuis, N., Deutscher, R., Schultz, S., & Jamshidi, A. (2018). The new NGSS classroom: A curriculum framework for project-based science learning. *American Educator, 42*(2), 23–27.

Huberman, M., Bitter, C., Anthony, J., & O'Day, J. (2014). *The shape of deeper learning: Strategies, structures, and cultures in deeper learning network high schools.* American Institutes for Research.

Huberman, M., Duffy, H., Mason, J., Zeiser, K., & O'Day, J. (2016). *School features and student opportunities for deeper learning: What makes a difference?* American Institutes for Research.

Krajcik, J. S., & Czerniak, C. (2013). *Teaching science in elementary and middle school classrooms: A project-based approach* (4th ed.). Routledge.

Krajcik, J. S., & Shin, N. (2014). Project-based learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (2nd ed.) (pp. 275–297). Cambridge University Press.

Larmer, J., Mergendoller, J. R., & Boss, S. (2015). *Setting the standard for project-based learning: A proven approach to rigorous classroom instruction*. ASCD.

Lucas Education Research. (2015). *AP teacher perspectives on project-based learning in the Knowledge in Action curriculum: Key findings from teacher survey study*.

Meyer, A., Rose, D. H., & Gordon, D. (2014). *Universal design for learning: Theory and practice*. CAST Professional Publishing.

Miller, E. C., & Krajcik, J. S. (2019). Promoting deep learning through project-based learning: A design problem. *Disciplinary and Interdisciplinary Science Education Research, 1*(7).

National Academies of Sciences, Engineering, and Medicine (2018). *How people learn II: Learners, contexts, and cultures*. The National Academies Press.

O'Reilly, T., & McNamara, D. S. (2007). The impact of science knowledge, reading skill, and reading strategy knowledge on more traditional "high stakes" measures of high school students' science achievement. *American Educational Research Journal, 44*(1), 161–196.

Parker, W. C., & Lo, J. (2016). Reinventing the high school government course: Rigor, simulations, and learning from text. *Democracy and Education, 24* (1).

Polman, J. L., Stamatis, K., Boardman, A. G., & Garcia, A. (2018). Authentic to whom and what? The role of authenticity in project-based learning in English language arts. In J. Kay & R. Luckin (Eds.), *Rethinking learning in the digital age: Making the learning sciences count, 13th International Conference of the Learning Sciences (ICLS)* 2018, Volume 2 (pp. 1669–1670). International Society of the Learning Sciences.

Thomas, J. W. (2000). A review of research on project-based learning. Autodesk Foundation.

Zeiser, K. L., Mills, N., Wulach, S., & Garet, M. S. (2016). *Graduation advantage persists for students in deeper learning network high schools—Updated findings from the study of deeper learning: Opportunities and outcomes*. American Institutes for Research.

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