An Initial Logic Model to Guide OpenSciEd Research

Updated Version

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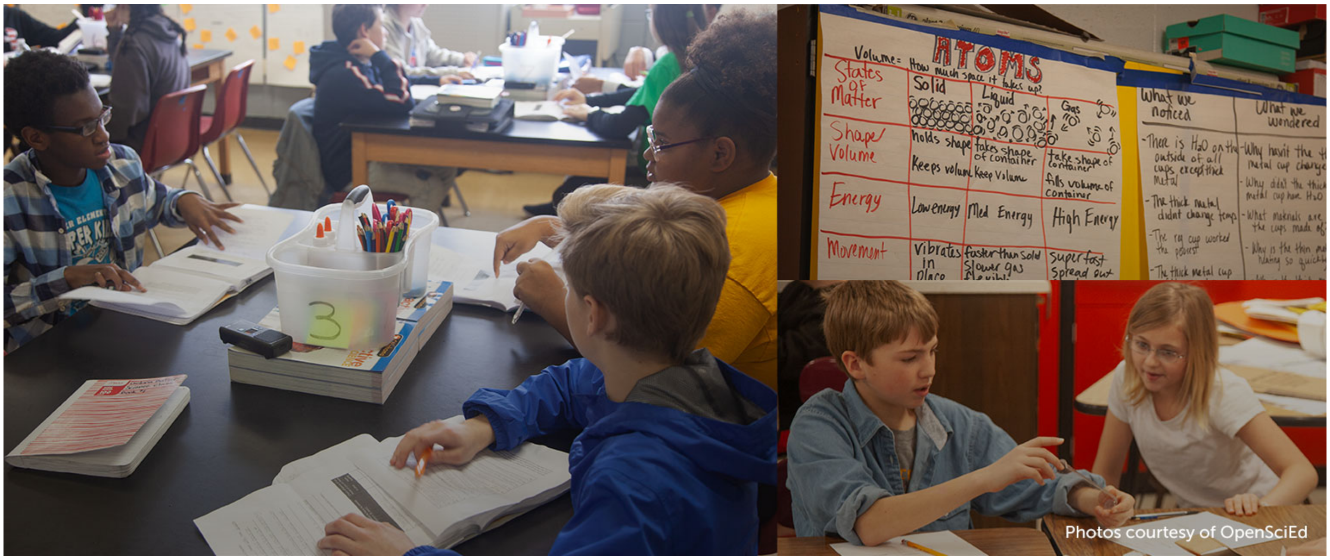

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Introduction

This white paper supports an ongoing effort to define a research agenda and catalyze a research community around the OpenSciEd curriculum materials. OpenSciEd is making high-quality, standards-aligned science curriculum materials freely available to all of the nation's students and teachers (Edelson et al., 2021; OpenSciEd, 2022). Rigorous research on these materials is needed in order to answer questions about the equitable design of instructional materials, impacts on student learning, effective and equitable classroom teaching practices, teacher professional development approaches, and models for school adoption that address the diverse needs of historically marginalized students in STEM. Research findings have the potential to advance the knowledge, skills, and practices that will promote key student, teacher, and system outcomes. The research agenda stands to accelerate the research timeline and stimulate a broad range of research projects addressing these critical needs.

To support the collaborative development and activation of the research agenda, we outline an initial logic model for OpenSciEd. A logic model describes the expected outcomes from an intervention and details the rationale for expecting impact based on learning sciences principles and design features. The logic model can shape research efforts by clarifying intended relationships among (1) the principles, commitments, and key affordances of OpenSciEd; (2) the components of OpenSciEd and how they are implemented and supported in classrooms, schools, districts, and states; and (3) the desired outcomes of OpenSciEd. These relationships outline hypotheses to be tested in potential research studies. In mapping these intended relationships, the logic model also highlights knowledge gaps for the field, which give rise to other research efforts that can better promote outcomes of interest.

Because OpenSciEd is a large-scale development and research ecosystem with many moving parts, the research agenda will focus on issues that are specific to OpenSciEd (rather than being generic to science education interventions broadly). Our logic model, therefore, does not exhaustively describe the full range of factors that could lead to the desired outcomes. Rather, we focus on OpenSciEd's most distinctive aspects to inform questions that can be best (or uniquely) answered through OpenSciEd research. Our logic model intends to be high-level so that it is useful to a variety of stakeholders and is intended as a starting point for more specific logic models that would inform particular research studies. While this paper does not aim to summarize the available research on OpenSciEd, a reading list on available relevant research will be subsequently made available to the research community.

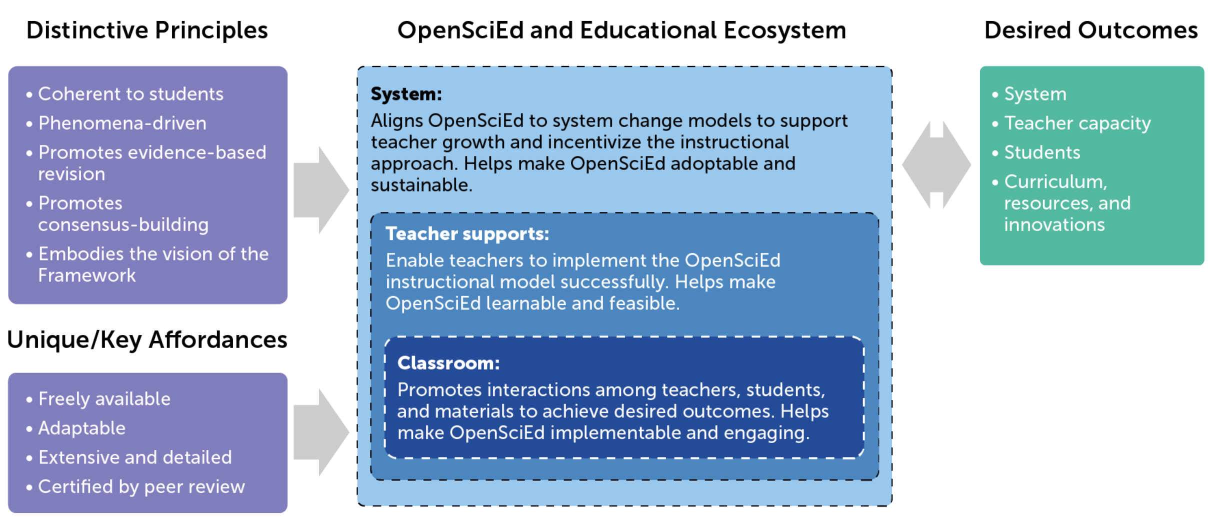
We used three main sources of information to articulate this model. (1) We reviewed the OpenSciEd resources themselves (available at openscied.org), including materials designed for students, teachers, professional development facilitators, and others who implement OpenSciEd. (2) We conducted interviews with OpenSciEd leaders, iteratively refining the model based on multiple conversations with them. (3) We synthesized reports and manuscripts (cited in the References) describing the principles, features, and desired outcomes of OpenSciEd.

An Initial Logic Model

Our overall model (Figure 1) links two types of inputs, three levels of the U.S. educational ecosystem that are targeted by OpenSciEd intervention, and four broad categories of desired outcomes (system, teacher capacity, students, and resources and innovations). The double arrow indicates a two-way relationship between the features and structure of OpenSciEd and the outcomes. For instance, innovations that emerge from adoption and/or implementation of OpenSciEd then become part of the ecosystem, further promoting the desired outcomes. We describe each of these components in detail below.

Figure 1

An initial logic model to guide OpenSciEd research



Inputs

Distinctive Principles. OpenSciEd's distinctive principles reflect students' intended classroom experience with OpenSciEd. Collectively, these principles reflect the vision of the [K-12 Framework for Science Education] (National Research Council, 2012; NGSS Lead States, 2013) and build on decades of research in science education and learning sciences about how instruction improves learning through relevance, collaboration, agency, and engagement with the authentic practices of science (Reiser et al., 2021).

- **Coherent to students.** In contrast to typical views of curricular coherence from the perspective of a science expert or curriculum designer, the logic of OpenSciEd instructional sequences reflects a storyline that are coherent from the student perspective. Each lesson is motivated by questions students generate in order to explain a phenomenon or solve a problem. Activities elicit, value, and build upon students' prior ideas. Students and teachers jointly decide on the next steps in investigations and identify what evidence is to go further. As a result, at any given time, students are expected to understand not only what they are doing, but also why they are doing it in the context of the investigation.

- **Phenomena-driven.** Student learning is motivated by attempting to make sense of anchoring phenomena related to the science learning targets. Learning is structured by iterative cycles of investigating phenomena, improving explanations, developing models, or creating designs with new evidence, and further questioning. Anchoring phenomena are complex and relevant and are revisited over the course of the investigation to test ideas.
- **Promotes evidence-based revision.** Students' ideas and questions determine what evidence to collect. Students seek and use evidence to figure something out as they build and revise their explanations, models, and arguments. Investigations provide evidence to build new science ideas instead of confirming pre-taught ideas, and students ask for evidence from their peers and suggest ways to gather additional evidence. Evidence can be used to problematize students' current thinking and help them think about where to go next.
- **Promotes consensus-building.** Classroom routines support students in the work of scientific argumentation and negotiating consensus in order to identify questions, develop plans, and develop explanations and models. Tasks are set up for students to engage in science and engineering practices through a balance of individual or pair work, small group work, and whole class work. During this process, students have opportunities to use, build upon, and critique others' ideas. The process of achieving consensus is supported by a classroom culture that encourages risk-taking and revising perspectives based on the availability of new evidence.
- **Embodies the vision of the *Framework*.** OpenSciEd materials center the three-dimensional vision of the Framework by promoting the integration of disciplinary core ideas, scientific and engineering practices, and crosscutting concepts. This vision goes beyond traditional visions of science proficiency as primarily content knowledge and emphasizes the "doing" of science and connections across the natural science disciplines and engineering.

Collectively, these principles promote equitable participation by giving students agency over their own learning and explicitly valuing students' ideas, experiences, and backgrounds. Enacting these principles creates a class community that values the diversity of knowledge and perspectives students bring to science class. Of course, as investigators pose specific research questions, they may emphasize the existing principles differently or add additional principles.

Unique/Key Affordances. A handful of unique and key affordances reflect the nature of OpenSciEd as open materials. These affordances offer specific advantages not only for district adoption but also for accelerating research in science education.

- **Freely available**. Licensed under Creative Commons CC BY 4.0, all OpenSciEd materials—designed for students, teachers, and professional learning facilitators—are freely available. This makes high-quality, standards-aligned instruction accessible to all students, especially those who have the greatest need, and to school systems that would otherwise not be able to afford high-quality materials. Making materials freely available has other benefits as well. For instance, it benefits research so that the materials can be more readily investigated, leading to improvements in design and implementation. It helps intermediaries, such as professional development (PD) providers, support districts with adoption and implementation. Eliminating the cost of instructional materials can also enable districts to redirect monies from curriculum to teacher professional learning. Regarding research, free materials may be important because they reduce barriers to use, adoption and spread, enabling available resources to be used in other ways to advance teaching and learning.
- **Adaptable.** Unlike commercially published products, all OpenSciEd materials (being open under a Creative Commons license) can be adapted, customized, or localized to meet the specific needs of the communities who use them. For example, adaptations to student materials could center local phenomena or socioscientific issues that have greater relevance to students and their communities. Teacher support materials could be modified to adhere to district-specific constraints on professional learning. The capacity to freely adapt materials is also highly amenable to design-based research—for instance, research studies can readily compare the relative benefits of alternate versions of materials for students or teachers.
- **Extensive and detailed.** The many types of materials and detailed nature of guidance within them are designed to promote OpenSciEd's distinctive principles with students, teachers, PD leaders, and other stakeholders. The level of detail responds to the extensive supports that are needed to implement novel approaches to classroom science instruction and recognizes that support needs will vary widely across contexts.
- **Certified by peer review**. OpenSciEd student and teacher materials have undergone a rigorous peer-review process and have been certified for meeting the criteria for NGSS design. These criteria include integrating the three dimensions of the Framework, providing mechanisms for appropriate instructional supports, and ways for teachers to monitor NGSS-aligned student progress over the course of instruction.

OpenSciEd and Educational Ecosystem

The logic model describes ways that OpenSciEd design components target various levels of our educational ecosystem. We have nested these components in three levels to describe the hierarchical nature of their relationships. At the innermost **classroom** level, OpenSciEd promotes certain kinds of interactions among students, teachers, and the instructional materials to promote desired outcomes. These classroom-level interactions are enabled by **teacher supports** that promote teacher growth in a way that is needed to effectively implement the OpenSciEd instructional model. OpenSciEd must also be aligned to change models at the **system** level (e.g., district and state) to support teacher growth and incentivize the instructional approach. We elaborate on each of these three levels here.

Classroom. Figure 2 summarizes the distinctive instructional features of OpenSciEd (Reiser et al, 2021) and lists examples of research opportunities associated with classroom implementation.

Figure 2

OpenSciEd components and research opportunities at the classroom level

Classroom: Promotes interactions among teachers, students, and materials to achieve desired outcomes

Components:
- Teacher as facilitator
- Driven by student questions
- Lesson-to-lesson enactment
- Practice-based activities
- Problematization
- Opportunities for assessment

Research opportunities:
- Characterize implementation
- Technologies that support sensemaking
- Equitable and inclusive instructional practices
- Assessment systems
- Improvements over time
- Practical barriers

- **Teacher as facilitator.** The teacher's role is to create a context for learning, choreograph learning experiences, and facilitate productive social interactions. The curriculum materials avoid being prescriptive for teachers, but teachers follow routines that help structure activities and conversations that value students' ideas and perspectives.
- **Driven by student questions.** Investigating their questions and developing design solutions for the problem provide a context and motivation for students to figure out the target science ideas and give students a strong sense of agency in their own learning. Driving question boards help build a shared mission that a classroom learning community needs to figure out phenomena or solve a design problem. Instruction driven by student questions requires the materials and the teacher to be

anticipatory of these questions so that activities can respond to these questions and teachers can prepare accordingly.

- Lesson-to-lesson enactment. Transitions between lessons in units (at the closing of a lesson, the opening of the next lesson, or both) contain whole class navigation discussions to maintain coherence from the students' perspective. These conversations help students maintain a continual awareness of what they are doing and why they are doing it.
- Practice-based activities. In embodying the vision of the Framework, student materials are designed to promote science and engineering practices. As facilitators, teachers must also promote classroom interactions that engage students deeply with the practices. Classroom routines support students in the work of scientific argumentation and negotiating consensus in order to identify questions, develop plans for investigation, and develop explanations and models of the anchoring phenomena.
- Problematization. Units are designed to include key transition points or moments that prompt students to identify gaps in their understanding. These activities motivate students to ask new questions or refine their existing questions that lead to new investigations about the anchoring phenomenon or problem. Teacher materials identify what needs to be problematized in order to motivate the learning across the entire unit.
- Opportunities for assessment. Assessments ask students to make sense of specific and compelling phenomena using their understandings built during the unit. Evidence of students' NGSS-aligned science proficiency can come from numerous sources, such as students' consensus models or performance tasks that prompts students to apply target concepts to new scientific contexts.

Field test studies of OpenSciEd provide preliminary evidence of the promise of these components of instruction. Given ample professional learning opportunities (discussed below), teachers are able to feasibly implement OpenSciEd units as part of their regular classroom instruction. Students report that they find OpenSciEd instruction highly engaging, and levels of engagement within classes are the same across racial groups. Some future research opportunities include the feasibility of the instructional model for teachers who can only receive a modest amount of professional learning time; how learning technologies could support students and teachers in facilitating collaborative sensemaking; how students and teachers improve in their enactment of OpenSciEd when using it over multiple years; and characterizing practical barriers to successful implementation.

Teacher supports. OpenSciEd teacher supports are a comprehensive system of materials and structured professional learning experiences that enable teachers to implement the OpenSciEd vision successfully (Edelson et al., 2021; Short & Hirsch, 2020). Supporting materials include documents, workshop slides, and other resources for teacher and district PD facilitators. Professional learning experiences are four-day (or more) PD workshops that are grounded in the curricular materials and are designed to support teachers having wide ranging experience. Figure 3 summarizes the teacher supports components (themes and activities) and associated research opportunities.

Figure 3

OpenSciEd components and research opportunities at the teacher supports

Teacher supports: Enable teachers to implement the OpenSciEd vision and and promote teacher growth

Themes:
- Content understanding
- Unit storyline
- Goals for specific lessons, discussions, and activities
- Logistical and materials strategies

Professional learning activities:
- Engage in analysis of and reflection on problems of practice
- Highlight navigation and lesson-to-lesson enactment
- Immerse teachers in content from the student perspective
- Provide opportunities to collaborate and reflect with peers

Research opportunities:
- Adapting teacher supports to meet local needs
- Professional learning communities, coaching, and teacher-to-teacher support
- Supporting equity across classrooms
- How much professional development is needed and whether districts can provide it
- Supporting professional development leaders from non-science disciplines

OpenSciEd materials and professional learning activities have a unit specific approach that foreground the following themes.

- **Content understanding.** Activities provide teachers with the scientific content knowledge they need to be successful facilitators of the units. Deep content understanding helps teachers better guide class discussions, cultivate student questioning, and promote modeling practices, for example.
- **Unit storyline.** Teachers learn how navigation routines for a particular unit fit together to build understanding and coherence from the student perspective for the overall unit and learning goals.
- **Goals for specific lessons, discussions, and activities.** Activities support teachers to understand how each lesson fits into the overall storyline.
- **Logistical and materials strategies.** Activities prepare teachers for specific demonstrations or investigations that students participate in during the course of a unit.

Professional learning activities position teachers as learners by engaging them with curriculum materials, providing ample opportunities for discussion and reflection, and emphasizing the unique characteristics of the OpenSciEd instructional model.

- **Engage in analysis of and reflection on problems of practice.** Each PD session addresses focal problems of practice around which video is analyzed, tools are introduced, and participants reflect on their own classroom practice as well as what they experience in the PD in light of that focus. For example, some activities focus on how to facilitate sensemaking discussions. Teachers first consider the value of productive talk and its function in the instructional model, then analyze a segment of classroom video where the practice is used. Participants then discuss and practice in small groups. Activities use student artifacts and video cases to help connect to teachers' own practice as well as the focal problems of practice. These activities are incorporated in many places throughout the professional learning materials, particularly as video vignettes of classrooms used as prompts for discussion.

- **Highlight navigation and lesson-to-lesson enactment.** PD puts an explicit focus on navigation, to help teachers balance where students are in the moment with the next steps. Rather than going through the curriculum with equal attention to every lesson, teachers engage in some focused reflection on critical moments in the instructional sequence where their decisions have the greatest impact on the direction of the investigation. PD activities also present teachers with contrasting curricular cases, so pedagogy is not anchored to their experience with only one specific unit or discipline and teachers can more readily generalize pedagogy across units.
- **Immerse teachers in content from the student perspective.** Teachers are asked to "switch hats" and take a student perspective to experience the anchoring phenomenon routine for the unit. After experiencing the routine with the student hat, teachers then debrief and discuss it using their teacher hat. These discussions support teachers' content understanding and help them see the unit coherence from the student perspective.
- **Provide opportunities to collaborate and reflect with peers.** Teachers work closely with other teachers at similar grade levels and grade bands during the PD sessions. They also connect with other teachers on social media for support as they implement the materials with their students.

Collectively, these themes and activities achieve an overarching emphasis on equity by promoting instructional practices that engage students equitably. The focus of the teacher supports on the unit storyline, the student perspective, and student collaboration and consensus give teachers knowledge and tools they need to provide students with agency and value their students' knowledge and voices.

Implementing the OpenSciEd instructional model is challenging—many teachers must dramatically change their beliefs about what students are capable of and how science should be learned and taught.

Preliminary field test studies indicate that, while teachers find support materials to be helpful for classroom teaching, teachers require a substantial amount of professional learning time to implement OpenSciEd successfully, and there can be wide variation in how teachers implement the OpenSciEd instructional model. Key research opportunities related to teacher supports include: how support materials and PD can be adapted to meet local needs while maintaining their integrity to the OpenSciEd instructional model; how teacher-to-teacher supports such as professional learning communities and coaching models best support

OpenSciEd teachers; and the feasibility of teachers getting the extensive amount of PD needed to implement OpenSciEd successfully in the classroom.

System. OpenSciEd currently works in three particular ways with district and state partners to align to system change models (Figure 4). The system-level interventions enable state and district policies to support teacher growth and better incentivize the OpenSciEd instructional approach.

Figure 4

OpenSciEd components and research opportunities at the system level

System: Aligns OpenSciEd to system change models to support teacher growth and incentivize the instructional approach

Components:

- Collaborations with state officers who can help align to existing systems and effect change in states
- System of OpenSciEd professional development service providers with trained and certified facilitators
- Support districts in preparing to implement OpenSciEd

Research opportunities:

- Variation in implementation and adoption across states
- Re-allocation of resources from curriculum to professional learning
- Engaging families
- Accountability systems
- Strategic partnerships
- Building district capacity

- **Collaborations with state officers.** OpenSciEd leaders work directly with state education officers who provide insights into how materials and opportunities for teacher learning can best align with existing systems. State officers are also in a position to effect changes that can support teachers, such as providing resources and time for teacher professional learning.
- **System of professional learning service providers.** OpenSciEd is developing a system of professional learning providers with specific expertise in OpenSciEd. Facilitators are trained by OpenSciEd and are certified by earning a micro-credential that articulates pathways for continuous learning on the part of facilitators. These micro-credentials are particularly important to ensure consistency across facilitators who may lack experience with science PD or strong science backgrounds.
- **District support.** OpenSciEd works directly with districts to help them prepare to implement OpenSciEd. For example, teachers new to OpenSciEd will not be able to implement a full year of OpenSciEd curriculum right away. Districts can benefit from guidance on how to gradually phase the units into the existing science curriculum. In addition, districts need support to provide teachers with sufficient professional learning time to be successful, to set up support systems for teachers such as a professional learning community (PLC) or coaching, and institute policies or guidelines (if needed) that appropriately incentivize teachers to use OpenSciEd.

While preliminary studies with OpenSciEd do not currently address system-level components, research should examine the potential impacts of system factors on desired outcomes. Examples of system-level research opportunities include examining variation in OpenSciEd implementation and adoption across states based on differences in resources or power to incentivize; whether being freely available permits the reallocation of resources from curriculum to professional learning; how schools and districts build their capacity to successfully implement OpenSciEd; the role of strategic partnerships across stakeholders in materials adoption, improvement, and innovation; and how to engage students' families in understanding and supporting OpenSciEd's ambitious science learning model.

Desired Outcomes

We have identified four broad categories of desired outcomes for OpenSciEd: student outcomes; increased teacher capacity; system-level outcomes (e.g., districts, states, and policies); and resources and innovations that support curriculum implementation and student learning (Figure 5). We refer to these as desired outcomes because they reflect what designers hope to achieve through the intervention features, rather than what outcomes research has gathered evidence about to date. The goal of this section is not to provide an exhaustive account of the range of possible outcomes from OpenSciEd. Rather, we discuss a handful of examples from each outcome category that are currently of keen interest to science education stakeholders and that have the potential to inform important and tractable research questions. Furthermore, while certain outcomes are closely tied to certain aspects of OpenSciEd (for instance, student outcomes are tied to student materials design and classroom implementation), the logic model illustrates how outcomes result from factors at multiple system levels. For example, system structures support teacher professional learning, which in turn improves classroom implementation, promoting student outcomes.

Figure 5

Four types of desired outcomes from OpenSciEd and examples of each

Desired Outcomes

Student:
- NGSS-based learning outcomes
- Science engagement
  - Phenomena and problems
  - Classroom
  - Coursetaking
  - Community
- Autonomy
  - Science and engineering practices
  - Peer collaboration
- Outcomes are equitable within and across classrooms

Increased teacher capacity to:
- Implement OpenSciEd successfully and sustainably
- Engage all students equitably
- Sustain a classroom culture of "figuring out"
- Achieve self-efficacy

System:
- Deeply committed district adoption
- Broad adoption and infrastructure
- Teacher collaborations
- Shifts in accountability practices
- Teacher professionalism
- Increased resources to teacher professional learning
- Strategic partnerships

Resources and innovations:
- Refined and customized materials
- Technologies
- Assessment systems
- Adoption and implementation models

Student outcomes include but go well beyond **NGSS-based learning outcomes**, which reflect students' ability to integrate the three dimensions of science proficiency to explain phenomena and solve problems. Broader goals involve students recognizing the importance of science and its affordances for contributing to society as citizens.

- Students become **engaged with science** at multiple levels. Students engage with phenomena and problems that are authentic and meaningful to everyday life, and they participate as active and collaborative learners in classroom activities. More broadly, OpenSciEd aims to spur greater interest in science, potentially resulting in increased STEM coursetaking and greater engagement with scientific issues in their communities.
- In class, students apply scientific and engineering practices, both individually and in peer collaboration, with guidance from their teacher. Over the course of multiple units or years of study, it is hoped that students exhibit a degree of **autonomy** in applying these practices, both in the classroom and in their everyday lives.
- OpenSciEd's emphasis on student agency and valuing student ideas help ensure that **student outcomes are equitable, both within and across classrooms**. Equitable outcomes result from a combination of factors, including materials design, teacher instructional practices, teacher professional learning opportunities, and systemic supports that enable teachers to improve their practice over time.

Increased teacher capacity results from the growth that teachers must experience in order to implement OpenSciEd in ways that lead to desired student outcomes.

- Fundamentally, teachers must be able to **successfully and sustainably implement the OpenSciEd instructional model**. Achieving this will take time, requiring professional learning resources, teaching experience, and supportive school culture.
- Implementing OpenSciEd requires teachers to engage in **instructional practices that promote equitable engagement in science**. These practices complement the equitable design features of the student materials and aim to support students having diverse backgrounds, knowledge, and abilities.
- In the role of classroom facilitator, it falls largely on teachers to **sustain a classroom culture of "figuring out."** Teachers will learn to establish norms and set expectations for students to learn in ways they have not previously experienced. School districts can help develop this culture across teachers and schools so that it is part of students' mindset toward learning science from year to year.
- The ambitious nature of the OpenSciEd model can make some teachers anxious about their own ability to enact it. Extensive time for professional learning and teacher-to-teacher support will help teachers achieve a sense of **self-efficacy with implementing OpenSciEd**.

System outcomes include aspects of district and state systems, such as processes, partners, capacity, policies, and culture.

- The components of OpenSciEd are designed to help promote **deeply committed district adoption**. Deep commitment refers to districts adopting OpenSciEd as the prevailing approach (rather than a few select teachers using it). Districts should develop coherence in their science program placing OpenSciEd at the center, feel a sense of ownership over the materials, and achieve a district-wide culture of science teaching and learning aligned with OpenSciEd's instructional approach.
- OpenSciEd needs to be not only deeply adopted, but also **widely adopted**. With its detailed and open design and its system of supports, OpenSciEd strives to be feasibly adoptable for districts. OpenSciEd recognizes that materials adoption is not merely a decision that district leaders make at a moment in time; rather, it is a process involving the entire community that needs to be supported. Wide adoption refers not only to the number of districts who adopt, but also to their diversity. OpenSciEd must therefore be feasible for districts that have less flexibility to innovate and implement new instructional models; these are the districts that likely need OpenSciEd most. OpenSciEd also needs to be widely adopted so that its features and affordances can be tested at scale.
- OpenSciEd aims to promote a district culture of **teacher collaboration** in forms such as mentoring, peer-support, coaching, or professional learning communities. Districts should create collaborative structures that preclude teachers from having to tackle the challenges of OpenSciEd on their own. Teacher collaboration across grades and grade bands also helps achieve coherence across teachers and schools.
- Certain district- or state-level expectations for teachers and students may be at odds with some aspects of the OpenSciEd instructional model. **Shifts in accountability systems** will need to align with continuously evolving views of classroom science teaching and learning.
- Curriculum materials should not require teachers only to enact highly prescribed instructional sequences in ways that diminish teachers' agency and circumvent their unique expertise and style. A goal of OpenSciEd is to **promote teacher professionalism** by enabling teachers to leverage their expertise to make difficult instructional decisions that respond to the ideas, interests, and needs of their students and communities.
- Acquiring high-quality curriculum materials at no cost offers districts the opportunity to **increase resources directed toward teacher development**. For example, resources could be used to improve science instruction in other ways, such as procuring better equipment, improving technology infrastructure, and supporting other staff such as coaches or curriculum specialists.
- OpenSciEd presents opportunities for **strategic partnerships** to tackle complex problems of practice and policy. These partnerships can involve diverse stakeholders, such as researchers, teachers, school/district/state leaders, developers, scientists, and intermediaries.

Resources and innovations will emerge as districts adopt OpenSciEd and adapt it to meet local needs. The range of possible innovations that result cannot be anticipated, but we briefly describe a few examples.

- Open materials lend themselves to **rapid iterative refinements and local customizations**. A major challenge for customized materials is maintaining integrity to the OpenSciEd model. Adaptations of OpenSciEd should not compromise the basic instructional principles in attempting to facilitate implementation.
- OpenSciEd is currently designed to be accessible to districts having limited technology infrastructure. School systems that have ample technology capacity may wish to leverage **classroom technologies** that can uniquely support OpenSciEd units. For example, computer-based tools could support students with articulating and refining scientific questions or teachers with lesson-to-lesson navigation.
- OpenSciEd will eventually be a full course of study for K-12 science. **Assessment systems** complementing OpenSciEd could help teachers, school and district leaders, and families continuously monitor students' progress across units, years, and grade bands.
- As OpenSciEd increases its reach, new **adoption and implementation models** will emerge that address the uniqueness of districts and their communities. These new models will in turn be used and refined by other districts, building collective knowledge about how districts can successfully adopt and implement OpenSciEd right out of the gate.

Illustrative Research Opportunities

We illustrate two examples of how the logic model helps identify a research opportunity that leverages the unique affordances of OpenSciEd, connects design features at multiple levels, and produces specific outcomes.

Research Opportunity: District models for adopting OpenSciEd. Districts will have unique curriculum and teacher professional learning needs based on state policies, district resources, and student populations. Important questions to investigate include: How do districts adapt OpenSciEd student and teacher materials to address the specific needs of their students and teachers? To what extent do these adaptations preserve the integrity of OpenSciEd's distinctive principles and features? What kinds of teacher-to-teacher support do they use (e.g., coaching, mentoring, professional learning communities), and are these support methods successful?

These questions bridge the System (district adoption, supports for districts) and Teacher Support (materials customization, professional learning) levels of the OpenSciEd ecosystem, and they connect to outcomes related to teacher capacity and materials innovations. A detailed logic model for this research could elaborate additional connections across district and school structures, ways that teachers engage in professional learning, and what teachers learn from these experiences.

Research Opportunity: Customizing student materials to meet the needs of specific student populations. Open materials invite instructional designers to develop instructional supports for specific student populations such as dual language learners or students with disabilities. Important questions to investigate include: How can OpenSciEd materials be customized to support these student populations? What supports do teachers need to implement them successfully? Do these supporting customizations improve student outcomes, and how?

These questions bridge the Teacher Supports (teacher materials and professional learning design) and Classroom (student materials design) levels of the OpenSciEd ecosystem, and they connect to equitable student outcomes such as learning, autonomy, and engagement. A detailed logic model to guide this research could elaborate specific connections between materials design features, student need, and specific desired student outcomes.

Summary and Next Steps

The logic model, which will be refined and elaborated over time, is just the initial step of an ongoing process to articulate and catalyze an OpenSciEd research agenda. The scope of OpenSciEd is too broad to be investigated in just a handful of research studies. OpenSciEd research needs to be a community-based effort addressing a wide range of system levels, outcomes, learning contexts, and student populations. This research will go beyond what is typical for static curriculum materials (questions about whether materials are effective, for whom, and under what conditions). Aligned with the visions of OpenSciEd's leaders, developers, and educators, we at Digital Promise see OpenSciEd to be the center of a living ecosystem of science education research. How can innovations such as customizations, extensions, supporting tools, and adoption models meet the needs of students, teachers, districts, and their communities? What system-level supports and policies are needed to realize the potential of these innovations? The logic model is one tool (of many yet to come) that can help tie our collective work together.

Along with those who are already working on OpenSciEd, we are eager to engage the science education research community in ongoing collaboration to identify research opportunities, form partnerships, gather information, and share insights. Toward the launching of the research agenda, we will continue to disseminate documents, opportunities, and other resources that enable all members of the science education community to participate in OpenSciEd research. We look forward to supporting your efforts.

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