A Field-Driven, Equity-Centered Research Agenda for OpenSciEd

Updated Version

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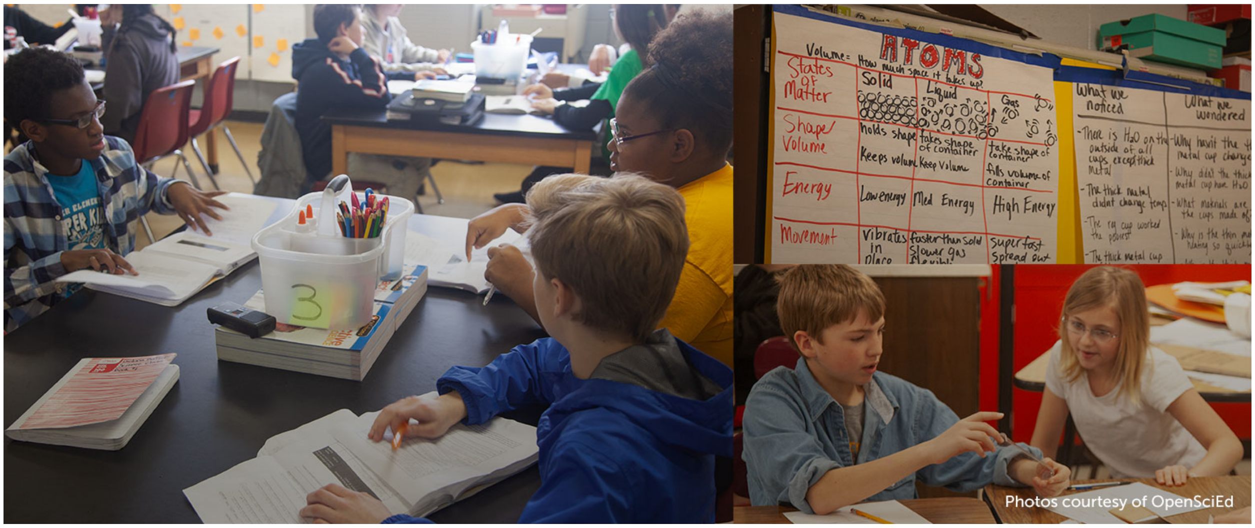
March 2022



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Accelerating Innovation in Education

Carnegie Corporation of New York

OpenSciEd

Suggested Citation

McElhaney, K., Baker, A., Kasad, Z., Roschelle, J., & Chillmon, C. (2022, March). *A field-driven, equity-centered research agenda for OpenSciEd: Updated version* [White paper]. Digital Promise. https://doi.org/10.51388/20.500.12265/153

Acknowledgments

We are grateful for the collaborations with many of our colleagues. First, we thank all the working group participants for their enthusiasm, thoughtfulness, and insights into science education research, policy, and practice. This white paper reflects the collective wisdom of all these individuals; the full list of participants and their affiliations appears as an Appendix. We thank our program committee (Daniel Damelin of the Concord Consortium, Tamara Heck of the Michigan Department of Education, Okhee Lee of New York University, Ann Rivet of Teacher College at Columbia University, and Tina Vo of the University of Nevada, Las Vegas) for their essential ongoing contributions and for expertly facilitating the working groups. We thank the OpenSciEd team (James Ryan, Sarah Delaney, and Matthew Krehbiel) for their insightful conversations and suggestions. We thank Daniel Edelson of BSCS Science Learning, Kate McNeill of Boston College, and William Penuel of the University of Colorado at Boulder for their thoughtful feedback on our artifacts and generative discussions. We thank our plenary session panelists (Angela DeBarger of the William and Flora Hewlett Foundation, Michael Ford of the National Science Foundation, Tiffany Neill of the Oklahoma State Department of Education, Eileen Carlton Parsons of the University of North Carolina at Chapel Hill, and Tricia Shelton of the National Science Teachers Association) for providing their unique perspectives on a preliminary version of this research agenda. Finally, we are grateful to Jim Short for invaluable guidance and the Carnegie Corporation of New York for supporting this work.

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Introduction

OpenSciEd (2022) is a set of Creative Commons licensed, freely available curriculum materials addressing the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013). OpenSciEd is based on a set of distinctive instructional principles (Reiser et al., 2021) and professional learning approach (Edelson et al., 2021; Short & Hirsch, 2020) that uniquely enable research to address important knowledge gaps about science learning, teaching, and implementation. Rigorous research on these materials is urgently needed in order to answer questions about the equitable design of materials, impacts on student learning, effective and equitable classroom teaching practices, teacher professional development approaches, and models for school adoption and adaptation that address the diverse needs of historically marginalized students in STEM. These findings have the potential to advance the knowledge, skills, and practices that educators need to support student success. The OpenSciEd leaders anticipate eventual adoption by 40% or more of the nation's schools. Because of this potentially large adoption, research centered on OpenSciEd has the possibility for large contributions to improving teaching and learning.

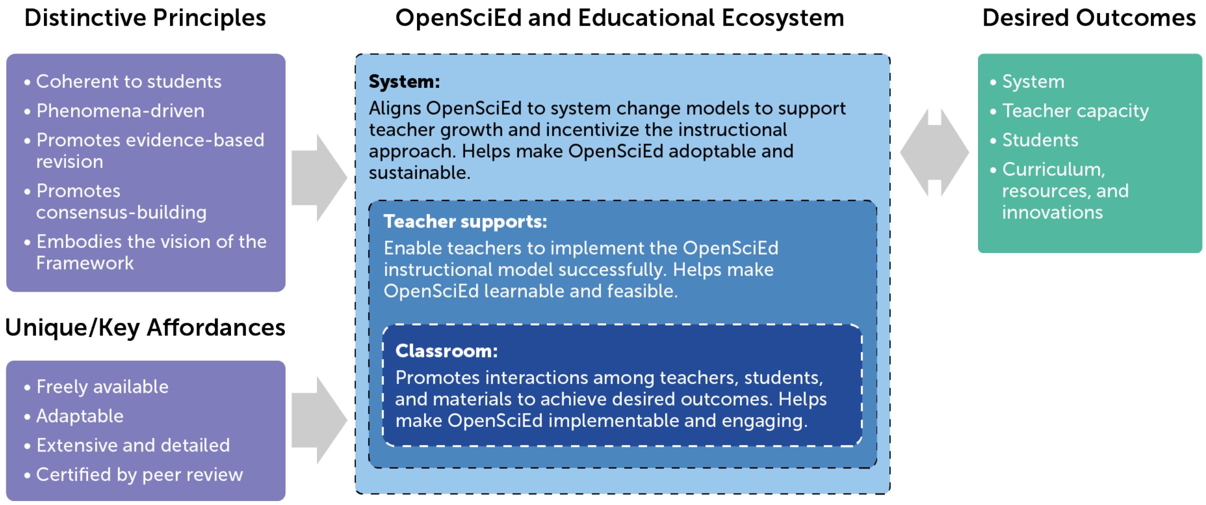
In order to catalyze the research community around OpenSciEd, Digital Promise, with support from the Carnegie Corporation of New York, has developed the OpenSciEd Research Agenda. Early on, we determined that three broad relationships between OpenSciEd and a research community could be fruitful. OpenSciEd *enabled* research encompasses questions in science education and beyond that can be best answered using OpenSciEd. OpenSciEd *inspired* research aims to drive innovations based on OpenSciEd's distinctive features and affordances. OpenSciEd *partnership* research would address questions of mutual interest to researchers and OpenSciEd developers. This paper details the processes utilized to frame the research agenda, recruit stakeholders and engage them in activities to generate research questions, and identify emergent themes for future OpenSciEd research.

A Logic Model to Guide OpenSciEd Research

To support the collaborative development of the research agenda, in a previous paper, we have articulated a logic model for OpenSciEd (McElhaney et al., 2022). A logic model describes the expected outcomes from an intervention and details the rationale for expecting impact, based on learning sciences principles. 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 how OpenSciEd is implemented and supported in classrooms, schools, districts, and states; and (3) the desired outcomes of OpenSciEd. We reproduce that logic model in Figure 1 and provide a brief overview of it below (the model is elaborated in greater detail in the previous paper). In this paper, we leverage the relationships expressed in this model to synthesize and elaborate themes that emerged from our research agenda activities.

Figure 1

An initial logic model to guide OpenSciEd research



Our overall model links inputs, multiple levels of the U.S. educational ecosystem that are targeted by OpenSciEd, and 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. One anticipated use of the logic model is to suggest opportunities for research and to establish the broader context for any specific research question.

The inputs to the model include OpenSciEd's **distinctive principles** and **key affordances**. The distinctive principles reflect students' intended classroom experience with OpenSciEd. Collectively, these principles reflect the vision described in *A Framework for K-12 Science Education* (National Research Council, 2012) 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 practices of science. These distinctive principles include (1) being coherent to students, (2) being phenomena-driven, (3) promoting evidence-based revision, (4) promoting consensus-building, and (5) embodying the vision of the Framework. Collectively, these principles promote equitable participation by giving students agency over their own learning and explicitly valuing students' ideas, experiences, and backgrounds.

The 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. These enabling features are that the materials are (1) freely available and creative commons licensed, (2) adaptable, (3) extensive and detailed, and (4) certified through a rigorous peer-review process for meeting criteria for NGSS design.

We describe the **educational ecosystem** surrounding OpenSciEd as having three nested components. (1) At the innermost **classroom** level, OpenSciEd promotes certain kinds of interactions among students, teachers, and the OpenSciEd materials to promote desired outcomes. (2) These classroom level interactions are enabled by **teacher supports** that promote teacher learning in a way that is needed to effectively implement the OpenSciEd instructional model. (3) OpenSciEd must also be aligned to **systems change** models (such as at the district and state levels) to support teacher growth and incentivize the instructional approach.

Finally**,** in conversations with OpenSciEd leaders, we have identified four broad categories of **desired outcomes** for OpenSciEd: (1) equitable student outcomes (e.g., NGSS-based outcomes, student agency and autonomy); (2) increased teacher capacity (e.g., classroom implementation, sustaining classroom culture); (3) system-level outcomes (e.g., districts, states, and policies); and (4) resources and innovations that support curriculum implementation and student learning (e.g., technologies and tools). 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.

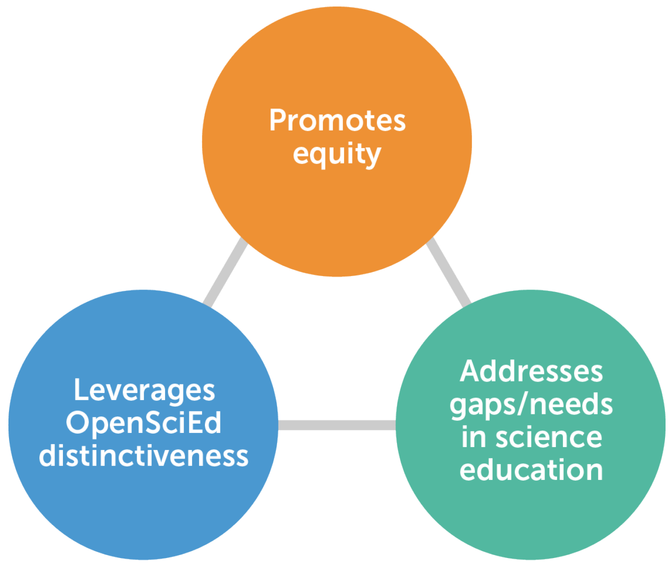
Description of the Working Sessions

Criteria for Generating and Refining OpenSciEd Research Questions

A very important step in organizing any research program or project involves generating specific research questions. Research questions often start out vague and become more specific and focused as a research team iterates on its plans. To guide convening participants in conceptualizing initial research questions, we found it helpful to suggest initial criteria for research questions that would be worth pursuing and refining. In particular, we framed potential research questions around three primary criteria (Figure 2): that they promote equity, leverage the distinct features of OpenSciEd, and address salient gaps in science education research.

Figure 2

Three primary criteria for articulating and refining OpenSciEd research questions



Promoting Equity. We approached the development of the OpenSciEd Research Agenda with an intentional focus on equity, which informed participant recruitment, workshop design, and research question development and refinement. Broadly, educational equity can be defined as follows:

> *Ensuring equally high outcomes for all participants in our educational system; removing the predictability of success or failures that currently correlates with any social or cultural factor; interrupting inequitable practices, examining biases, and creating inclusive multicultural school environments for adults and children; and discovering and cultivating the unique gifts, talents and interests that every human possesses. (National Equity Project, 2021)*

This definition is consistent with the goals of the Framework as well as OpenSciEd's equity design stance. For instance, the Framework identifies the promotion of equity among its guiding principles, noting that building upon the cultural assets of students will benefit their learning of science and, ultimately, science itself. The Framework also calls for equalizing opportunities to learn and promoting inclusive science instruction by leveraging student funds of knowledge, building on interest and identity, and making diversity visible, among other approaches. For example, inclusive science instruction requires a fundamental shift in teaching that positions students as the primary generators of knowledge (as opposed to teachers and textbooks).

OpenSciEd is also designed to address equity concerns in numerous ways across its ecosystem, in response to the Framework. Within the middle school design specifications, OpenSciEd has developed an *equity design stance*, with commitments to visible diversity, learning experiences focused on relevance and community purpose, support for multilingual learners, and supporting equitable sensemaking. The commitment to relevance and equitable sensemaking appears within the instructional model, embedded within the teaching routines that support unit coherence from the student perspective (Reiser et al., 2021). For example, during the *anchoring phenomenon* routine, students are prompted to identify related phenomena to the one the unit is based upon, drawing connections to their personal lives. Likewise, in the *putting pieces together* routine, students are engaged in discourse and consensus building with teachers supporting diverse language and discussion approaches, and generating a sense of belonging in the sensemaking classroom community. Throughout the OpenSciEd units and sequences, these routines provide opportunities for equitable student participation in the explanation of scientific phenomena.

Given the importance of equity and the intention of OpenSciEd to address it, we recommend that all research questions include a specific equity focus. The open nature of OpenSciEd lends itself to wide variety of potential research; rather than promoting a single equity perspective in the development of research questions pertaining to OpenSciEd, we would encourage researchers to take an equity approach that is appropriate for the context of their proposed study and make clear connections between equity goals and the potential outcomes. For example, in a study designed to understand how best to adapt OpenSciEd to foster a sense of belonging in Black students, an equity perspective that foregrounds rightful presence (e.g., Calabrese Barton & Tan, 2019) could be well suited to guide materials development by helping value and legitimize students' cultural perspectives for science investigations. However, a study that examines affordances of OpenSciEd for dual language learners could foreground design perspectives that support language use in science (e.g., Haas et al., 2021). Alternatively, a study that examines technology supplementation of OpenSciEd could focus on equitable access and structural barriers to technology and digital learning to inform design and development.

Leveraging OpenSciEd Distinctiveness. A key goal of the OpenSciEd research agenda is for it to be specific to OpenSciEd, rather than enabling research using any science curriculum materials. As such, over the course of the working group meetings, we prompted participants to articulate, discuss, and refine questions that leverage one or more OpenSciEd distinctive principles and/or key affordances, as illustrated by the inputs on the left side of the logic model (Figure 1). For example, the distinctive practice of eliciting students' own questions as part of instruction gives rise to potential research questions around how teachers can facilitate instruction around those questions and what classroom tools can effectively support student-driven inquiry. The adaptability of OpenSciEd materials gives rise to potential research questions around the nature of high-quality adaptations and the role of adaptation in achieving sustainable adoption by districts. The opportunity for broader impacts from research will expand when research has a strong fit to what makes OpenSciEd distinctive.

Addressing Gaps and Needs. Finally, to ensure that the research agenda is both helpful and timely for the OpenSciEd community, we aim to elicit research questions that address the most pressing existing knowledge gaps and problems of practice. For example, potential areas for knowledge advancement and innovation in science education include assessment, curriculum design and implementation, learning theory, technology, teacher professional learning, pedagogy, and policy. Toward this end, we engaged a wide range of participants with experience in these areas to identify the most salient gaps and needs, as described below.

Working Group Meeting Structure

To develop the research agenda collaboratively and reflect current needs of the field, we recruited a group of 79 science education stakeholders with varying levels of knowledge of and experience with OpenSciEd, paying special attention to ensuring gender and racial diversity in our recruitment efforts. Participants included researchers (academic and non-academic), designers, district- and school-level practitioners, state education officials, professional learning providers, program officers, and others. Participants were surveyed to identify their interests, and were placed into one of five groups: assessment, pedagogy, professional learning, curriculum and technology. These larger groups then participated in three 90-minute working group sessions with facilitators from Digital Promise and the project program committee.

In Meeting 1, participants generated an initial set of ideas and questions informing potential OpenSciEd-based research, with a particular focus on addressing salient problems of practice in science education. In Meeting 2, participants collectively prioritized and refined the ideas (by improving their alignment to the three criteria described above) and sorted questions according to emergent themes. Between Meeting 2 and Meeting 3, participant small groups were asked to elaborate a research question of interest by outlining a potential research study that could answer the question. In Meeting 3, participants provided feedback on the research study designs and refined the research questions accordingly.

We analyzed artifacts produced from these sessions, including collaboratively edited slides with research themes and questions, research study outlines, and meeting notes taken by facilitators. We synthesized the insights from these artifacts into themes that were crosscutting with respect to the five topics areas. We used the logic model to examine the intersection of these themes with the classroom, teacher, and system levels of implementation and how the themes align with particular outcomes of interest.

Emergent Themes

In synthesizing the working group outputs, we identified the following four themes that were prevalent across all questions across topic areas: (1) promoting student agency and participation, (2) promoting authentic science and the Framework vision, (3) materials customizations and adaptation, and (4) adoption, implementation, and sustainability. These four themes are interconnected and not mutually exclusive. For example, the adaptation of materials can support stakeholders in improving classroom-level implementation or sustainability of professional learning; promoting authentic science through teacher practice may lead to more opportunities for student agency in science classrooms. We observed that themes (1) and (2) broadly concern student outcomes of interest, while themes (3) and (4) broadly concern processes or approaches for achieving those outcomes.

Theme 1: Student Agency and Participation

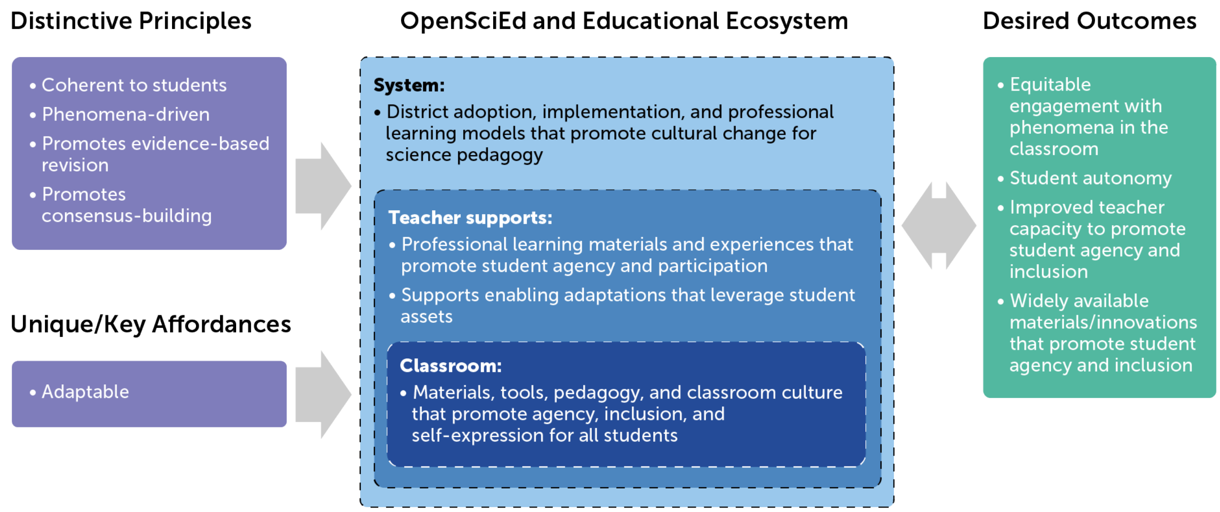
This theme addresses how curriculum materials and tools can promote equity by increasing students' sense of agency, opportunities for self-expression, and pursuit of their goals through student-driven science investigations and how teachers can support all students in achieving agency. Figure 3 illustrates what components of the logic model are most strongly connected to this theme. For instance:

- **Inputs.** OpenSciEd's distinctive principles of being coherent to students, phenomena-driven, and promoting the continuous revision of student ideas through consensus-building all contribute to student agency and participation. Adaptations to OpenSciEd can further enable ways to leverage student assets and value the contributions of all students to collective sense-making.
- **Enacted Ecosystem.**
    - At the **classroom** level, this theme concerns student-centered pedagogy, the design of teaching materials and tools, and how classroom activities can be customized to offer students opportunities for self-expression and collaboration.
    - At the **teacher support** level, it concerns the design of professional learning materials and experiences that help teachers promote student agency and participation in the classroom.
    - At the **system** level, it concerns in-district professional learning and implementation models that preserve opportunities for student agency and participation, as well as the roles of intermediaries (e.g., professional learning providers, curriculum developers) in supporting these opportunities.
- **Outcomes.** Outcomes of interest related to this theme encompass equitable student learning and science engagement, teacher pedagogy, classroom culture, and the innovation of materials and tools promoting student agency and participation.

Example research questions aligned with this theme that arose in the working group meetings include: How can technologies support or enhance students' capacity for self-expression and support students to elicit their own questions, ideas, and experiences? and How can OpenSciEd materials and professional learning support teachers in making adaptations that respond to their students' ideas, identities, experiences, needs, interests, communities, and local contexts?

Figure 3

OpenSciEd logic model, through the lens of student agency and participation



Theme 2: Promoting the Framework Vision

This theme addresses how curriculum materials and tools can equitably promote students' engagement and learning in practice-based science (within and across classrooms) and the support and structures needed for teachers to develop capacity for ambitious instructional models. Figure 4 illustrates what components of the logic model are most strongly related to this theme.

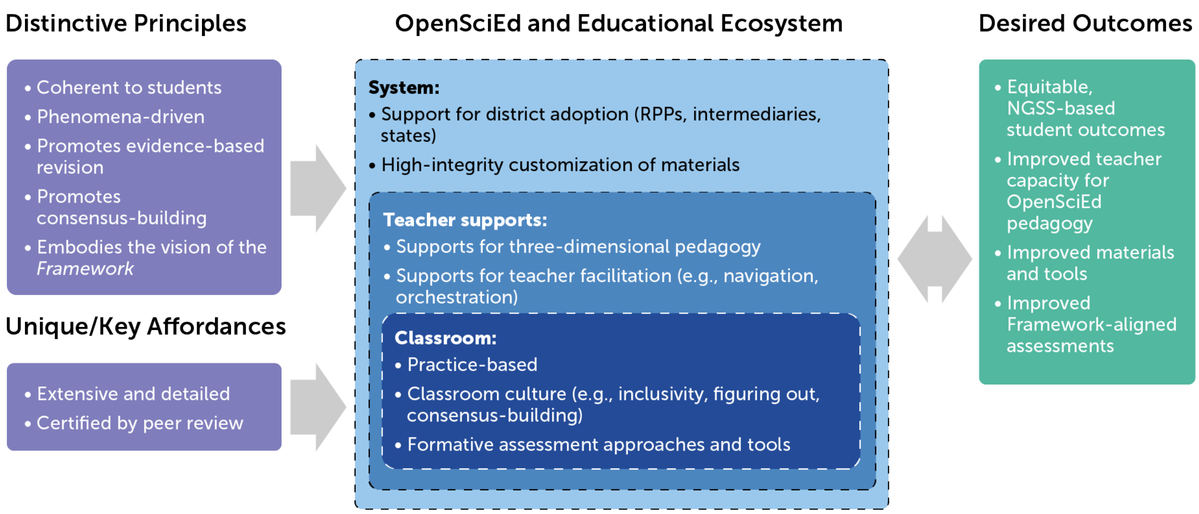
- Inputs. OpenSciEd's distinctive principles of being coherent to students, phenomena-driven, promoting revision of student ideas through consensus-building, and the commitment to embody the vision of the Framework itself all contribute to promoting the Framework goals. The extensive and detailed nature of the materials and that OpenSciEd is certified as NGSS-aligned are key affordances for districts to implement a Framework-inspired vision of science education.
- Enacted Ecosystem.
    - At the **classroom** level, this theme concerns students' engagement with the three dimensions of the Framework and practice-based science activities, as well as NGSS-aligned, classroom-based assessment approaches.
    - At the **teacher support** level, it concerns the design of professional learning materials and experiences that help teachers enact pedagogy that promotes practice-based science in the classroom.
    - At the **system** level, it concerns the alignment of students' and teachers' experiences with Framework-based district and state standards.

- **Outcomes.** Outcomes of interest particularly related to this theme encompass NGSS-based student outcomes, teacher capacity to promote Framework-based learning, and innovations that further support students' engagement with practice-based science.

Example research questions aligned with this theme that arose in the working group meetings include: How do teachers' interactions with OpenSciEd's educative features and professional learning materials help grow teachers' vision of what their students are capable of doing in science classrooms? and What instructional design features and teaching practices promote the use of crosscutting concepts as a tool for understanding phenomena?

Figure 4

OpenSciEd logic model, through the lens of promoting the Framework vision



Theme 3: Materials Customization and Adaptation

This theme addresses how customization of open materials occurs, how customizations of teacher and student materials can promote deep district adoption, and how customized materials equitably meet the specific needs of teachers and students. Figure 5 illustrates what components of the logic model are most strongly related to this theme.

- **Inputs.** It is critically important for customizations and adaptations of OpenSciEd materials to preserve all of OpenSciEd's distinctive principles. A key issue concerning this theme is the extent to which OpenSciEd is adapted, implemented, and adopted with integrity at all system levels.
- **Enacted ecosystem.**
    - At the **classroom** level, this theme concerns how high-integrity customizations can shape classroom interactions in ways that build on shared knowledge and experiences.

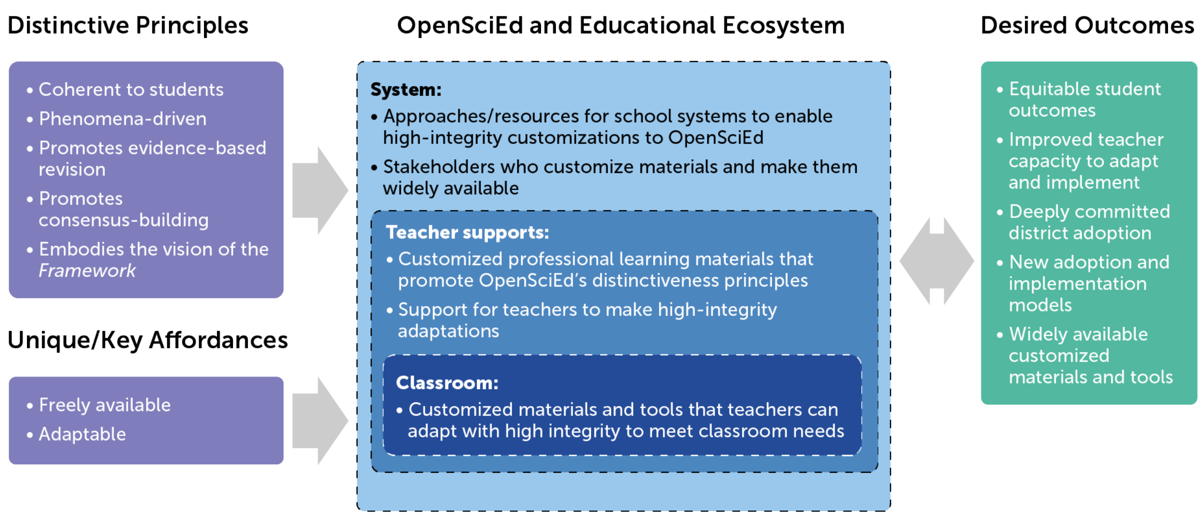
- At the **teacher support** level, it concerns the customizations to professional learning materials that meet districts' needs and constraints and supports teachers' need to adapt materials for their classrooms effectively and with integrity.
- At the **system** level, it concerns how customized materials can be made widely available (such as for specific student populations) and the extent to which customized materials maintain integrity to OpenSciEd's distinctive principles.

- **Outcomes.** Outcomes of interest particularly related to this theme encompass how customizations promote equitable outcomes, improve teacher capacity, promote deeply committed district adoption, and inform new curriculum adoption and implementation models.

Example research questions aligned with this theme that arose in the working group meetings include: What customizations to teacher professional learning materials contribute to sustainable district adoption of OpenSciEd? and What adaptations do teachers make to curriculum materials to meet their students' needs?

Figure 5

OpenSciEd logic model, through the lens of materials adaptation and customization



Theme 4: Sustainable Adoption and Implementation

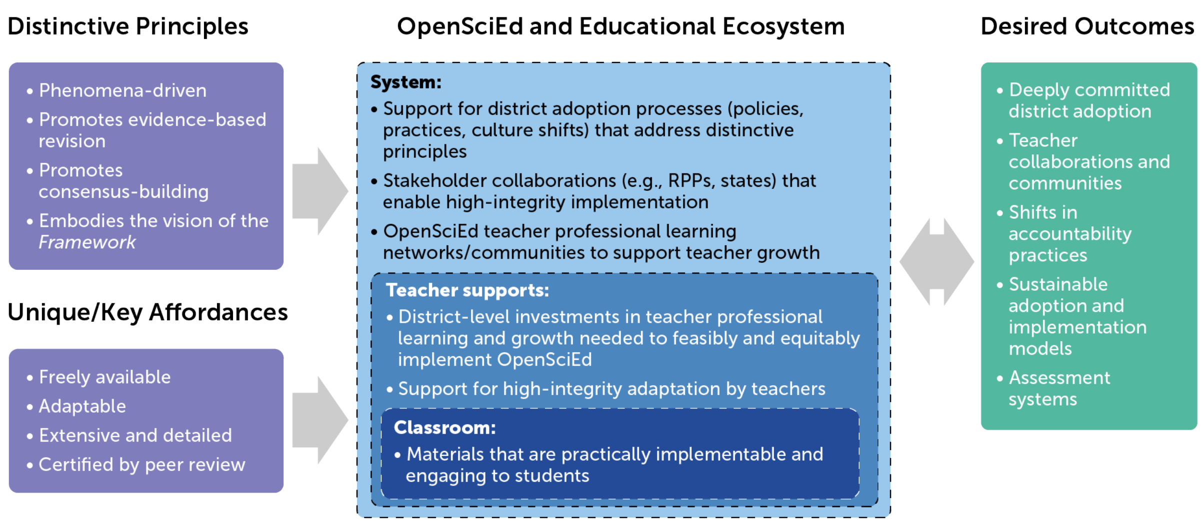
This theme addresses sustainable and equitable models for adoption, implementation, and teacher professional learning, how customization can support these models and the roles of diverse stakeholders (such as states, intermediaries, and researchers) in articulating and implementing these models. Figure 6 illustrates what components of the logic model are most strongly related to this theme. For instance:

- **Inputs.** The full range of OpenSciEd's distinctive principles and key affordances will inform sustainable models of district adoption and classroom implementation. For instance, to what extent will the free availability of OpenSciEd materials enable districts to direct additional financial resources to professional development of science teachers? What will be the role of customizations in districts achieving sustainable adoption and implementation models?
- **Enacted ecosystem.**
    - At the **classroom** level, this theme largely concerns the practicality of implementing OpenSciEd in the classroom.
    - At the **teacher support** level, it concerns how teachers can receive sufficient professional learning opportunities and how supporting resources for teachers can be designed to promote sustainable implementation.
    - At the **system** level, it concerns support for districts to adopt OpenSciEd sustainably and the role of stakeholders (e.g., researchers, states, intermediaries) in providing this support.
- **Outcomes.** Outcomes of interest particularly related to this theme encompass deeply committed district adoption, teacher collaborations and communities, shifts in accountability practices, and novel curriculum adoption models.

Example research questions aligned with this theme that arose in the working group meetings include: How do districts provide the time and resources teachers need to implement OpenSciEd in ways that meet the needs of all students? and How do teachers form communities across districts and locales to share ideas and provide mutual support for implementing OpenSciEd?

Figure 6

OpenSciEd logic model, through the lens of sustainable adoption and implementation



A Potential Research Project: Teacher Supports for Curriculum Customization

We describe an example potential research project that was conceived by a team of participants[1] in the working group on curricular materials titled *Customizing OpenSciEd materials to students' local contexts, identities, and funds of knowledge*. The project would address questions about how to design supports for educators to support them in customizing OpenSciEd materials. The effort to address this challenge could include both (1) professional learning strategies targeting teachers' capacity to adapt for local relevance and cultural responsiveness and (2) design heuristics for new curriculum development and revisions to existing materials, making it easier for teachers to make these adaptations.

This project would involve teachers who have experience teaching OpenSciEd units and who wish to develop customizations to meet specific needs of their students or community contexts. Together, researchers, curriculum and professional learning developers, and teachers would identify key funds of knowledge and aspects of students' science identity to target in curricular customizations and, based on teachers' previous experience, identify aspects of OpenSciEd units that would benefit from these customizations. Curriculum developers would work with teachers to develop the customizations and work with researchers to articulate and refine design heuristics for future OpenSciEd development to better support such customization. Professional learning developers would work with teachers and researchers to design and test professional learning supports for teachers engaging in customization.

The research team would conduct classroom observations, student focus group interviews, and teacher interviews as part of classroom studies to determine how the customized units promote outcomes of interest (such as equitable student engagement, classroom participation, integrity of implementation). The research team would also conduct observations of professional learning sessions and interviews with teachers and instructional leaders to determine to what extent the design heuristics and professional learning supports better enabled teachers to customize curriculum for local relevance and cultural responsiveness.

This potential project is driven by the challenges of designing coherent, NGSS-aligned curriculum materials. The design process is highly demanding, typically requiring large teams and substantial time. Moreover, materials designed for use at scale (such as OpenSciEd) are necessarily designed for a national audience. Customizing materials for local contexts (e.g., local phenomena, specific cultural relevance) requires substantial pedagogical design

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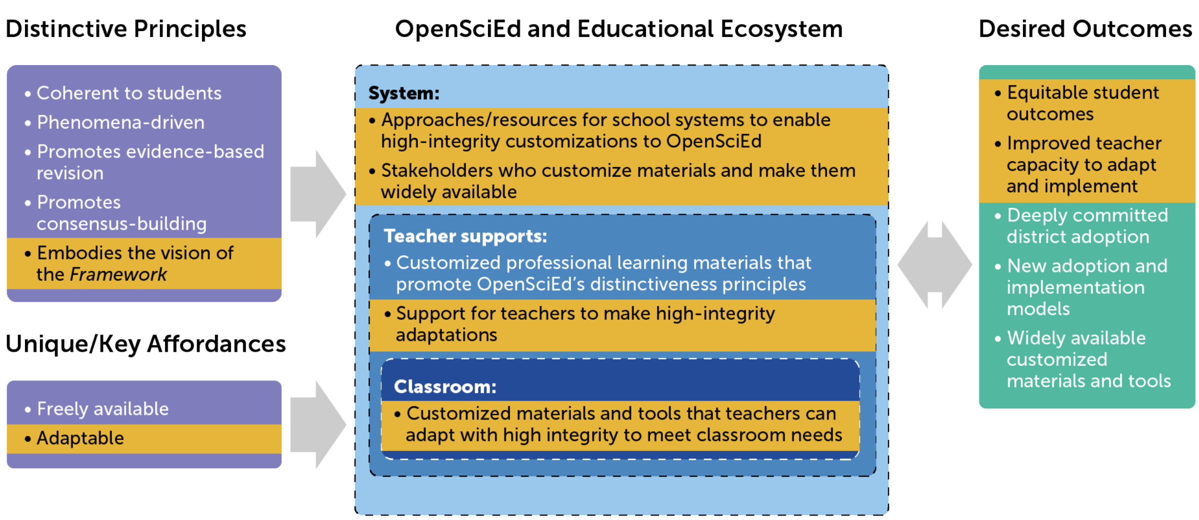
[1] This research project idea was articulated by Amy Deller (Ann Arbor Public Schools), Ravit Duncan (Rutgers University), Barbara Hug (University of Illinois Urbana-Champaign), and Suzanna Loper (Lawrence Hall of Science). Team members are listed alphabetically and contributed equally to the project conceptualization.

capacity as well as prohibitive time and effort that teachers and district personnel do not have.

This project is an example of research that addresses the three primary criteria for OpenSciEd research (described above). It leverages OpenSciEd's distinctiveness as one of only a handful of high-quality science instructional materials designed for use at scale by a national audience, and the only one with a Creative Commons license that facilitates adaptations to specific learning contexts. It centers equity by focusing on ways that community-based, place-based, and social-justice-focused curriculum can be more effective for engaging underrepresented learner populations in STEM by better accessing students' funds of knowledge (Moll et al., 1992). It addresses key knowledge and practice gaps in how to support educators to make and implement customizations feasibly, and how these supports can help customized materials maintain integrity to the NGSS. This prospective study could also yield generalizable strategies that could be used by professional learning specialists and curriculum designers broadly. The salient components of the OpenSciEd logic model addressed in this prospective project are illustrated in Figure 7.

Figure 7

Mapping the example research project to the OpenSciEd logic model (materials adaptation and customization theme)



Limitations

In synthesizing the workshop artifacts, we identified several ideas that were not featured prominently in workshop discussions but that we believe should inform future OpenSciEd research efforts. First, the research questions that were raised in our working group sessions tended not to distinguish strongly among needs at different grade bands, likely because only middle school materials were widely available when the workshops were held. As materials for other grade bands become available, it will eventually be necessary to identify how research priorities for different grade bands differ. For example, models for implementing OpenSciEd will be very different in high school than in elementary school. Questions about curriculum design, teacher professional learning, and pedagogy will therefore differ across these grade bands.

Second, the working group discussions tended to focus on the dramatic pedagogical shifts teachers must make to implement OpenSciEd, as its instructional model is particularly distinctive in the way it aims to build on students' own ideas and position teachers as classroom facilitators. Researchers must still recognize that the Framework content itself still presents novel challenges for students, teachers, and districts, such as integrating the three dimensions of proficiency, or making connections across the science, engineering, mathematics, and computational thinking disciplines. OpenSciEd research will need to continue to address these existing questions in addition to specific questions about OpenSciEd distinctiveness. Teachers' knowledge of the Framework content remains a prerequisite to successfully implementing OpenSciEd.

Third, the workshop discussions of teacher learning and needs revolved primarily around in-service teachers, who have so far made the most extensive use of OpenSciEd materials. Questions about the potential for OpenSciEd to meet specific needs of pre-service teachers and teacher training programs merit attention. For example, having free access to adaptable, high-quality instructional materials could transform aspects of science teacher preparation, and OpenSciEd could help establish new approaches to science pedagogy across grade bands.

Fourth, workshop discussions about ways OpenSciEd can promote equity tended to center the student perspective, such as through curriculum design, pedagogy, and desired student outcomes. Less frequently discussed were ways that OpenSciEd can help address inequities faced by teachers and school systems. For instance, how will under-resourced districts be able to provide the necessary professional learning experiences and other support systems for teachers to successfully adopt a new and highly intensive instructional model? Or, to what extent do OpenSciEd professional learning materials meet the needs of teachers in rural districts who are asked to teach multiple science disciplines and/or students in multiple grade bands? How can OpenSciEd materials be adapted to meet the needs of these teachers?

Finally, there are practical issues to consider in parallel with OpenSciEd research goals. The ambitious nature of OpenSciEd necessarily introduces tensions between its vision and the practical realities of teaching (Edelson et al., 2021). In reality, teachers are squeezed between state and local policies and the immediate needs of their students. They have limited resources, instructional time, and opportunities for professional learning and reflections. The success of curriculum materials can be inhibited by logistical classroom constraints. The extensive and detailed nature of the teacher supports can make them unwieldy for teachers to use. While teachers are invited to customize materials, customization takes time and could compromise the integrity of the materials to the Framework vision or the OpenSciEd pedagogical model. A key goal of OpenSciEd research will be to resolve these tensions between the ambitious vision and the practical realities of teaching by identifying what aspects of OpenSciEd are (and are not) negotiable, and what it takes for teachers, schools, and districts to "take the leap" to OpenSciEd adoption.

Envisioning an OpenSciEd Research Community

The wide-ranging conversations that occurred in our working groups point to the large scope of OpenSciEd. While OpenSciEd is in a strict sense a set of instructional materials, its affordances of being freely available and adaptable transform it from an *intervention* to an *ecosystem*. This ecosystem includes high-level systems change models associated with widespread adoption of OpenSciEd as well as the full range of innovations and refinements that will support OpenSciEd teaching, learning, and implementation. It also could include the emergence of an ongoing research community around OpenSciEd.

The potential breadth of the OpenSciEd ecosystem speaks to its ambitious goals: to redefine K-12 science teaching and learning, create lasting change in classrooms, schools, and districts, and make high-quality science instructional materials both available and feasible for all of the nation's precollege students. To achieve this vision, OpenSciEd flips the existing development paradigm: rather than the process starting with scholars and curriculum developers, then trickling down to classrooms to be implemented with fidelity, OpenSciEd begins with the student perspective (equity, agency, ideas, and coherence), encourages educators to customize the materials to the interests of their students and communities, and invites a community of innovators to expand what the materials are capable of achieving and the audience that can be reached.

Given the broad scope of the OpenSciEd ecosystem, the extent of its intended adoption, and the range of stakeholders that are involved, a research community collectively can achieve a great deal more than what individual researchers can by working in isolation. For instance, we envision OpenSciEd research striving to answer complex, system level questions such as identifying which systems implementation factors are most responsible for driving outcomes, determining what stage of implementation do these factors come into play, and modeling factors that influence adoption and implementation at different system levels. Answers to such questions can emerge only from the synthesis of many research studies conducted across a multitude of learning contexts and involving diverse participants.

An OpenSciEd research community would include all types of stakeholders, including district and state leaders, teachers, designers and developers, intermediaries, and students and their families. The community would make use of tools that enable coordination of research efforts and synthesis of findings. It would also offer ways to rapidly share and disseminate findings, innovations, and lessons learned (in the form of both successes and failures) to broad audiences, accelerating cycles of iterative improvement. Lastly, it would assist in forging partnerships (including research-practice partnerships) that engage complementary expertise needed to answer complex questions. We hope that this research agenda constitutes the first step toward catalyzing a broader research community around OpenSciEd.

Using the Research Agenda

For researchers, we hope this white paper will support the development of research proposals by articulating salient questions of interest to the field; informing research design; and highlighting beneficial expertise and partnership for conducting OpenSciEd research. Researchers can point to the questions identified here as being systematically identified by a diverse community of education stakeholders to be pressing for the field, thereby bolstering an argument for their importance. The questions here also center issues of equity, which are of paramount importance to our society (and, consequently, to most funders). The questions generated by this collaborative process are still "high level"—they represent broad areas and topics to be addressed in research—and would likely need to be more narrowly specified for a submittable research proposal.

The workshop discussions have also given rise to a handful of even broader questions that we hope researchers will tackle as a community. For instance, how can research about teaching and learning pivot from traditional questions around content knowledge, pedagogy, and curriculum design, to new essentials (that arise when using OpenSciEd) such as using performance assessments, customizing or adapting materials, promoting positive student identity and agency, and supporting classroom orchestration? How do processes and outcomes for students, teachers, and districts evolve over long time periods? How can efficacy, effectiveness, and scale-up research methodologies better align to high-quality curriculum materials that are intended to be flexible, adaptable, and open to student-driven inquiries, rather than asking only whether a fixed "intervention" is implemented with fidelity to achieve a narrowly defined outcome? Finally, OpenSciEd research has an opportunity to inform education beyond the discipline of science and offer insights into the nature and sustainability of open education in K-12. OpenSciEd can provide evidence about what is needed to build capacity with new learning and teaching models based on open educational resources across disciplines.

For school and district practitioners and state officials, the research agenda illustrates how research cuts across levels of the OpenSciEd ecosystem by articulating how desired outcomes connect backward to ecosystem components and, in turn, OpenSciEd's distinctive principles and affordances. For instance, a curriculum director could come to better understand how OpenSciEd can promote equitable, Framework-aligned classroom instruction and identify what district system changes are needed to achieve it. Teachers who are looking to implement research-based practice could find a starting point for participatory action research within their own classes. The research agenda has also identified opportunities for educators to partner with researchers and developers to help meet their needs. These partnerships could include research-practice partnerships or involve regional education centers that provide technical assistance to school districts.

From a state perspective, the research agenda informs how materials adoption processes could be influenced by open materials, particularly given the current dearth of available high-quality materials in science. In contrast to textbook adoption processes, which involve the creation of an approved list by a state textbook committee, high-quality and customizable open materials could transform these materials approval processes. The research agenda also has the potential to inform policies that promote sustainability of OpenSciEd at scale by pointing to new implementation models, approaches for the use of curriculum funds, and ways to increase the reach of OpenSciEd by supporting under-resourced school systems.

Finally, the research agenda identifies roles in OpenSciEd research for stakeholders such as professional learning providers, technology developers, curriculum developers, and assessment developers. The OpenSciEd ecosystem can be fertile ground for innovations and best practices in these areas. Engaging these stakeholders as partners will be essential for pursuing large-scale research questions about customizations, implementation, adoption, and sustainability.

We invite all who aspire to transform K-12 science education to participate in these research efforts and help realize OpenSciEd's vision. We hope this synthesis constitutes a stepping stone toward creating a vibrant OpenSciEd research community, yielding the insights needed for supporting today's students to become the global citizens and leaders our society needs for the future.

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