SCHOOL BOARD ACTION REPORT

DATE: July 27, 2019
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For Introduction: August 28, 2019
For Action: September 4, 2019

1. TITLE

Discovery Research K-12 (DRK12) Grant from the National Science Foundation

2. PURPOSE

Seattle Public Schools (SPS) Science Department has received a Discovery Research K-12 (DRK12) Grant from the National Science Foundation, in partnership with University of Washington School of Education to help support elementary teachers' learning of the new science standards and deepen their competencies to teach science. This action report would allow the superintendent to accept the Discovery Research K-12 (DRK12) Grant from the National Science Foundation, which was awarded on July 1, 2019 in the amount of $500,000 per year for a three (3) year period, in the total amount of $1,500,000 for the three (3) years.

3. RECOMMENDED MOTION

I move that the Board authorize the Superintendent to accept the Discovery Research K-12 (DRK12) Grant from the National Science Foundation, which was awarded on July 1, 2019 in the amount of $500,000 per year for three (3) years, for a total of $1,500,000 for the three (3) year grant period.

4. BACKGROUND INFORMATION

a. Background:

The DRK12 grant will provide the SPS science team with a partnership with nationally recognized leaders in science education to support elementary teachers' learning of the new standards and deepen their competencies in the complex and rigorous pedagogy to support student learning and growth in science, which goes well beyond simply training elementary teachers to implement and teach the new science curriculum. Only 5% of those who apply for this grant receive the award and it is an honor to be recognized by the National Science Foundation.

This grant project will cultivate and study a district-wide Networked Improvement Community (NIC) model aimed at advancing ambitious and equitable elementary science instruction and student learning outcomes for all students, with a particular focus on culturally and linguistically diverse students. Through the grant, SPS science will build a sustainable infrastructure for training elementary science teachers. The grant will study the implementation of localized improvements in regional communities and networked improvement across the district via teacher leaders and use of the district's already-established learning management system. Project aims are: 1) to improve all students' written and spoken scientific models, explanations and arguments, with a particular focus on equity in classroom teaching, 2) Develop infrastructure for collaborative learning and improvement in elementary science for all SPS, and 3) to articulate a set of measurements sensitive to the development of professional capital.

b. Alternatives:

Do not accept the awarded funds from this grant and forgo the opportunity.

c. Research:

This DRK12 grant project builds on University of Washington's previous National Science Foundation-funded work that developed research-based sets of science teaching practices and tools, networks of culturally and linguistically diverse science teachers across the school district, and engagement of SPS elementary teachers in a practice-based professional learning model.

The grant project's Networked Improvement Community (NIC) model addresses a critical need in the United States--the need for models of professional learning and knowledge generation that can advance reform-oriented instruction across an educational system. Partners from the University of Washington Ambitious Science Teaching group and Seattle Public Schools (SPS) aim to build a network that will build elementary teacher capacity in engaging all K-5 students in rigorous and equitable science learning by improving practices and tools that scaffold for full participation in classrooms. The grant project will use the Networked Improvement Community (NIC) model to help generate knowledge about ambitious and equitable science teaching practices with a particular focus on 1) noticing students' cultural resources and experiences and planning for culturally relevant, place-based phenomena that are meaningful to children's lives, 2) positioning students as active knowledge builders, encouraging students' collaboration and learning from one another in constructing models, explanations and arguments & supporting culturally and linguistically diverse students in classroom discourse, and 3) soliciting feedback from these students about their learning and their experiences.

The Networked Improvement Community (NIC) model will intentionally draw on varied expertise throughout the system (e.g., elementary teachers at international schools, secondary science teachers with specific content expertise, district-level science specialists, and educational researchers) to broaden systemic capacity and advance rigorous and equitable learning opportunities. Our research on the approach and how it develops will inform the work of districts across the country that are seeking to form

NICs or support reform-oriented instruction at scale, as well as research-practice partnerships engaging in collaborative improvement work.

5. FISCAL IMPACT/REVENUE SOURCE

The grant awarded to SPS science will be a revenue of up to $500,000 a year for three (3) years.

Expenditure: ☐ One-time ☐ Annual ☒ Multi-Year ☐ N/A

Revenue: ☐ One-time ☐ Annual ☒ Multi-Year ☐ N/A

6. COMMUNITY ENGAGEMENT

With guidance from the District's Community Engagement tool, this action was determined to merit the following tier of community engagement:

☐ Not applicable

☐ Tier 1: Inform

☒ Tier 2: Consult/Involve

☐ Tier 3: Collaborate

This work is building upon previous work with the University of Washington partners, collaborations of science teachers and family engagement.

7. EQUITY ANALYSIS

Seattle Public Schools is committed to eliminating opportunity gaps to ensure access and provide excellence in education for every student. Board Policy No. 0030, Ensuring Educational and Racial Equity was developed to work toward the district's mission to eliminate opportunity gaps. This grant project will advance a set of ambitious and equity-based practices and tools for identifying and building on culturally and linguistically diverse students' funds of knowledge and resources, which are vital to supporting educational outcomes for all students in SPS. Goals of Board Policy No. 0030 that will be supported through the DRK12 grant include equitable access to educational resources for all students and strengthening teachers' knowledge and skills for eliminating opportunity gaps.

8. STUDENT BENEFIT

The work of the DRK12 provides teachers with the tools to provide high quality, standards-aligned instruction across all abilities as well as grounding teachers in strategies to incorporate a student's life experience and cultures into the science curriculum as called for by the 2019-20 SPS Strategic Plan. This DRK12 grant project has strong potential to advance elementary science instruction and student learning outcomes across Seattle Public Schools' 74 K-5/K-8 schools serving approximately 28,000 elementary students. The DRK12 grant project will use the Networked Improvement Community (NIC) model to help generate knowledge about ambitious and equitable science teaching practices with a focus on:

- noticing students' cultural resources and experiences and planning for culturally relevant, place-based phenomena that are meaningful to children's lives
- positioning students as active knowledge builders, encouraging students' collaboration and learning from one another in constructing models, explanations and arguments & supporting culturally and linguistically diverse students in classroom discourse
- soliciting feedback from culturally and linguistically diverse students about their learning and their experiences.

Project goals are:
1) to improve all students' written and spoken scientific models, explanations and arguments, with a focus on equity in classroom teaching through,

a. Continued improvement of science teaching practices and tools
b. Collaborative investigation of equitable practices and tools
c. Provide science content support from district content specialists to broaden perspectives about students' science ideas

2) Develop infrastructure for collaborative learning and improvement in elementary science for all SPS elementary teachers through,

a. Development of regional Professional Learning Communities (PLCs) that include elementary and secondary teacher teams that build the infrastructure of support across the district.
b. Development of teacher leadership across system
c. Develop a network repository with vision tools of what is possible in diverse classrooms
d. Support principals in learning about classroom practices and supporting PLC learning

3) Track Networked Improvement Community (NIC) development and articulate a set of measurements sensitive to the development of professional capital by,

a. Monitoring practical measure development at each level of the NIC

9. WHY BOARD ACTION IS NECESSARY

☐ Amount of contract initial value or contract amendment exceeds $250,000 (Policy No. 6220)

☒ Amount of grant exceeds $250,000 in a single fiscal year (Policy No. 6114)

☐ Adopting, amending, or repealing a Board policy

☐ Formally accepting the completion of a public works project and closing out the contract

☐ Legal requirement for the School Board to take action on this matter

☐ Board Policy No. _____, [TITLE], provides the Board shall approve this item

☐ Other: ____

10. POLICY IMPLICATION

Per Board Policy No. 6114, the acceptance of Gifts, Grants and Donations of more than $250,000 must be approved by the School Board.

11. BOARD COMMITTEE RECOMMENDATION

This motion was discussed at the Audit and Finance Policy Committee meeting on August 19, 2019. The committee reviewed the motion and moved the item forward with a recommendation of approval by the full board on August 28, 2019.

12. TIMELINE FOR IMPLEMENTATION

Upon approval of this motion, funds granted on July 1, 2019 will be accepted and allocated as follows beginning in August 2019 through August 2022:

Summer 2019

- Obtain staff in the amount of 2.0 FTE to support project implementation. The additional staff will help to support our 1,400 elementary school teachers who teach science through professional development and supports throughout the implementation process.
    a. Equivalent of 1.0 FTE elementary specialist
    b. Equivalent of 5 X .2 FTE secondary specialists
- Summer institute that begins with orienting elementary teachers to equity frameworks, Ambitious Science Teaching (AST) practices, and emergent ambitious and equitable network practices; Teachers coordinate practices with math, literacy and Equity-Based teaching practices

School Year 2019-20

- Engage PLCs and teachers in noticing culturally and linguistically diverse students' ways of knowing
    - Develop and test tools that support equitable classroom cultures based on analysis of student work and practical measures

- Secondary science teachers will partner with teacher leaders to support regional PLCs to provide content area expertise for teachers, examine classroom artifacts and co-design tools with a focus on multiple ways of knowing scientific ideas

- Use district supported PLC structure to gather teachers from schools close in proximity, develop routines for examining student work and iterating on tools (4x annually)

- Iterate on facilitation and leadership practices through leadership meetings and co-design solutions to emergent problems of practice (for teacher learning and for student learning), network leaders to learn from varied practices at international schools, in bilingual programs, etc.
    - Use common assessment data and practical measures teacher surveys to inform decisions

- Create a bank of resources and tools for each grade-level, with tags describing how the tools supported ambitious and equitable learning
    - Teacher leaders serve as models by sharing examples of tools and student work on Schoology

- Integrate science-focused teacher meetings into existing structures for collaborative professional learning
    - Develop tools for instructional walks with administrators
    - Grow capacity for teacher leaders to participate in instructional walks

School Year 2019-20

- Refine, optimize, and iterate on these project outcomes in years two and three as we bring the second- and third-year rollout schools into the adoption.

13. ATTACHMENTS

- Attachment A: Project Overview (For Reference Only)
- Attachment B: Full Project Description: Building Professional Capital while Advancing Ambitious and Equitable Elementary Science Teaching (ASTEE) with a District-Wide Networked Improvement Community (NIC) Model (For Reference Only)
- Attachment C: DRK12 Driver Diagram (For Reference Only)

School Board Action Report

Discovery Research K-12 (DRK-12) Grant, September 2019

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For questions and more information about this document, please contact the following:

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This Board Action will allow the superintendent to accept the Discovery Research K-12 (DRK12) Grant from the National Science Foundation, which was awarded on July 1, 2019 in the amount of $500,000 per year for a three (3) year period, in the total amount of $1,500,000 for the three (3) years. This Report includes a set of supporting documents, some of which, by their nature, are not fully ADA-compliant.

Attachment A Project Overview

Building Professional Capital while Advancing Ambitious and Equitable Elementary Science Teaching (AST^{EE}) with a District-Wide Networked Improvement Community (NIC) Model

Overview: This Implementation and Improvement project, suitable for the Teaching Strand, addresses a critical need in the United States--the need for models of professional learning and knowledge generation that can advance reform-oriented instruction across an educational system. Partners from the University of Washington Ambitious Science Teaching group and Seattle Public Schools (SPS) aim to build a network that engages all K-5 students in rigorous and equitable science learning by improving practices and tools that scaffold for full participation in classrooms. Project aims are: 1) to improve all students' written and spoken scientific models, explanations and arguments, with a particular focus on equity in classroom teaching, 2) Develop infrastructure for collaborative learning and improvement in elementary science for all SPS teachers (equity of inclusion), and 3) to track NIC development and articulate a set of measurements sensitive to the development of professional capital. Building on our previous NSF-funded work that developed research-based sets of secondary science teaching practices and tools, networked secondary science teachers across a culturally and linguistically diverse school district to improve practices and tools, and engaged SPS elementary teachers in a practice-based professional learning model, this project will cultivate and study a district-wide NIC aimed at advancing ambitious and equitable elementary science instruction and student learning outcomes for all students, with a particular focus on culturally and linguistically diverse students. We will build toward sustainability, and study the implementation of localized improvement in regional communities and networked improvement across the district via teacher leaders and use of the district's learning management system.

Intellectual Merit: Using a networked improvement approach to support tangible advances and capacity-building in systems is relatively new and underexplored in the field of education. The proposed project will contribute to the field's understanding of the development and impact of a district-wide NIC focused on ambitious and equitable science instruction. Through a combination of short- and long-cycle iterations with system-wide measures and in-depth case studies over three years, we will document the evolution of the model and critical facets that support advances and sustainability -- capitalizing on variation within the system to understand what works, for whom, and under what conditions. We will intentionally document our iterative processes to contribute examples of what it looks like to test and refine a systemic approach to improvement. Importantly, we will use the NIC to help generate knowledge about ambitious and equitable science teaching practices with a particular focus on 1) noticing students' cultural resources and experiences and planning for culturally relevant, place-based phenomena that are meaningful to children's lives, 2) positioning students as active knowledge builders, encouraging students' collaboration and learning from one another in constructing models, explanations and arguments & supporting culturally and linguistically diverse students in classroom discourse, and 3) soliciting feedback from culturally and linguistically students about their learning and their experiences. We will examine how professional capital (decisional capital and social capital) develop around these equity foci in the network.

Broader Impacts: This project has strong potential to advance elementary science instruction and student learning outcomes across Seattle Public Schools -- a diverse district with 74 K-5/K-8 schools serving approximately 28,000 elementary students. We believe this project will advance a set of ambitious and equity-based practices and tools for noticing and building on culturally and linguistically diverse students' funds of knowledge and resources, which are vital to supporting educational outcomes for all students in SPS. The NIC model will intentionally draw on varied expertise throughout the system (e.g., elementary teachers at international schools, secondary science teachers with specific content expertise, district-level science specialists, and educational researchers) to broaden systemic capacity and advance rigorous and equitable learning opportunities. Our research on the approach and how it develops will inform the work of districts across the country that are seeking to form NICs or support reform-oriented instruction at scale, as well as research-practice partnerships engaging in collaborative improvement work.

Attachment B Full Project Description

Building Professional Capital while Advancing Ambitious and Equitable Elementary Science Teaching (AST^{EE}) with a District-Wide Networked Improvement Community (NIC) Model

Importance

The proposed project takes the challenges of scale and sustainability head-on in the context of advancing NGSS-supportive teaching practice across a large, culturally and linguistically diverse school district. Building on previous NSF-funded work, partners from the University of Washington Ambitious Science Teaching (AST) group and Seattle Public Schools (SPS) aim to cultivate and study a district-wide networked improvement community (NIC) (Bryk, Gomez, Grunow, & LeMahieu, 2015) to advance ambitious and equitable elementary science instruction. Using a networked improvement approach is relatively new and underexplored in the field of education, but holds promise for supporting tangible advances and capacity-building (Lewis, 2015).

Seattle Public Schools (SPS) is currently attempting something radical -- to swiftly shift K-5 science instruction *and* gear up the system for sustainable and equitable professional learning and improvement. SPS specifically wants to focus on the improvement of instruction that supports the vision of learning in the Framework for K-12 Science Education (NRC, 2012) and the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013). The aim is to position K-5 students not as consumers of content, but rather as capable sense-makers about the world who are active participants in the knowledge construction and evaluation work of science (Ford & Forman, 2006). SPS wants to engage all K-5 students, including the youngest of learners (NASEM, 2015), in scientific practices to develop understandings of core ideas and crosscutting concepts. They recognize that more rigorous and responsive forms of science teaching are needed to move away from typical patterns of teaching in elementary contexts where content is presented authoritatively, and students often engage in isolated hands-on activities with little opportunity for connecting these activities to larger questions or ideas (Banilower et al., 2013; NASEM, 2015.)

Supporting the development of reform-oriented instruction sustainably at scale is a critical challenge, as most often professional learning opportunities create significant but small pockets of change for short periods of time (Coburn, 2003). Further, many efforts to improve instruction are top-down approaches in which teachers are given little time to interpret and localize new instructional practices within their classroom contexts, leading to limited enactment (Allen & Penuel, 2015). Our approach to scale targets the design and substance of professional learning and its organization within SPS, balancing integration with existing district infrastructure and shifting the system in theoretically-grounded ways:

- Shift from professional development (PD) focused on how to use kit-based curricular materials to professional learning grounded in more generalizable sets of practices and tools (e.g., McDonald, Kazemi, & Kavanagh, 2013) that are the object of study and improvement (Coburn, 2003)
- Shift from teachers as individual practitioners to teaching as collaborative investigation, with mechanisms for jointly testing and refining systems of tools that support shared aims (e.g., Hiebert & Morris, 2012)
- Shift from centralized efforts directing professional learning to distributed knowledge-building and leadership (e.g., Hopkins, Spillane, Jakopovic, & Heaton, 2013), expanding ownership of the systemic work (Coburn, 2003)
- Shift from learning science as decontextualized facts, toward deep engagement with real-world, puzzling phenomena in ways that are authentic and relevant to students (Banilower et al., 2013)
- Shift from teaching lessons as prescribed by curriculum, to a focus on responsive teaching and building on all students' funds of knowledge (Thompson et al., 2016), with a particular emphasis on culturally and linguistically diverse students' knowledge (Rosebery et al., 2015)

Successfully implementing and integrating these shifts will require principles from NICs, multilevel knowledge-building and problem-solving system (Bryk, Gomez, & Grunow, 2011). In previous work, we have seen that a thoughtfully constructed NIC, with human and technical resources oriented toward shared aims and building on an initial set of teaching practices and tools (Windschitl, Thompson & Braaten, 2018), can enable the development of professional capital within a system (Hargreaves & Fullan, 2012) such that the system itself (as well as individuals and PLCs, Professional Learning Communities) builds capacity for sustained learning and improvement (Thompson et al., under review). Our research-practice partnership will iterate on a networked improvement approach in ways that are meaningful, actualizable, and ultimately sustainable in SPS' context.

Broader Impacts

This project has the potential to advance elementary science instruction and student learning outcomes across SPS -- a diverse district with 74 K-5/K-8 schools serving approximately 28,000 elementary students. Access to high quality instruction in SPS is inequitable with some students receiving zero science instruction and others benefitting from authentic model-based inquiry on a daily basis. The NIC model will intentionally draw on varied expertise throughout the system (e.g., elementary teachers at international schools, secondary science teachers with specific content expertise, district-level science specialists, and educational researchers) to broaden systemic capacity and advance rigorous and equitable learning opportunities. We believe this project will advance a set of ambitious and equity-based practices and tools for noticing and building on culturally and linguistically diverse students' funds of knowledge and resources (Moll, Amanti, Neff & Gonzalez, 1992, Rosebery et al., 2015), which are vital to supporting educational outcomes for all students in SPS. Our research on science education reform with an "all-comer" NIC model within a single-district will inform the work of other school districts across the country seeking support reform-oriented instruction at scale, as well as research-practice partnerships engaging in collaborative improvement work.

Results from Prior NSF Support

The proposed project builds on a history of NSF-funded work conducted in practice and in close partnership with school districts. Specifically, we are capitalizing on prior work in which we: 1) developed research-based sets of core science practices and tools, 2) cultivated a grade 4-12 NIC in a mid-sized, culturally and linguistically divers district that engaged school-based PLCs in continual improvement of science teaching practices and tools, and 3) piloted a blended, practice-based professional learning model with SPS that supported regional PLCs for teachers to build and refine practices and tools for K-5, which we describe below.

***DRL-0822016*: Developing and testing a set of core science teaching practices and tools (2009-2013)**

Early development work focused on partnering with teachers to articulate sets of well-established evidence-based practices that together constituted a framework of ambitious and equitable science teaching (Windschitl, Thompson & Braaten, 2018). In developing the framework, we pursued a vision of students discursively engaged in constructing models, explanations, and arguments around a puzzling, complex yet relevant scientific phenomenon -- a vision consistent with that of NGSS and what SPS envisions for its science learners. The supporting core sets of practices are described in several publications (Windschitl, Thompson & Braaten, 2018; Thompson, Windschitl, & Braaten, 2013; Windschitl, Thompson, Braaten, & Stroupe, 2012). In brief, the framework includes one planning-oriented set of practices (emphasizing important science ideas that connect and help to explain a phenomenon or related set of phenomena) and three enactment-oriented sets - eliciting and working with students' ideas, experiences, and language as legitimate classroom resources to build on; supporting students in making sense of evidence from activity in relation to their developing ideas; and pressing students to construct or revise explanations in light of evidence. Ongoing research demonstrates that these practices and supporting tools (artifacts that mediate students' and/or teachers' activities) have the potential to lift the intellectual rigor and responsiveness in classroom activity by engaging students with their prior knowledge as an equity move to help all learners feel connected and respected for the experiences that they bring (Kang, Windschitl, Stroupe, & Thompson, 2016; Stroupe, 2014; Thompson et al., 2016).

Figure 1. AST practices

***DRL-1315995:* Building Capacity for the Next Generation Science Standards through Networked Improvement Communities (2013-2017)**

A subsequent research-practice partnership project brought together school-based PLCs with teachers, coaches, teacher educators, administrators, and educational researchers from nine secondary schools and five elementary schools in a mid-sized culturally and linguistically diverse school district to inquire into the practices and tools described above. Importantly the secondary portion of the NIC involved all 100+ secondary science teachers in the district. We describe this model as an "all comers" NIC, as every teacher volunteered to participate. It is an example of "equity of inclusion" of teachers. We positioned teachers to collaboratively adapt and innovate with the AST practices and tools to address problems of practice in their own schools and classrooms. Teachers in the NIC participated in collaborative school-based PLCs and district-wide convenings to learn across contexts. PLCs examined student work, developed tools to support EBs (Emergent Bilinguals) and co-taught with one another using a Studio model. Test scores on standardized state assessments rose for all schools. The average relative passing rate improvement was 2.6% for an average participation rate of two years. With each additional year of project participation, there was a significant 8% improvement in the passing rate. The number of years of school participation explained 86% of the variation in science test passing rate improvement, a large effect size, and this did not differ for school percentage of students enrolled with free/reduced lunch.

In brief, we learned that: 1) Science and EB coaches (who were initially teachers in the district) were vital in promoting visions of instructional practice and collaboration, as they shared tools across schools and lead cycles of experimentation and reification with PLCs in each school (see yellow squares in the sociograms below); 2) knowledge of teaching was accelerated when PLCs collaborated to learn AST practices, then iterated on related smaller grain-sized practices and tools, including practices and tools that hybridized AST practices with EB teaching practices; and 3) planning, enactment, and reflection tools mediated learning, as 94% of all interactions in Year 4 used a NIC-developed tool or practice—this supported a common language and foci for improvement among NIC participants. Figure 2 shows how the network developed over time.

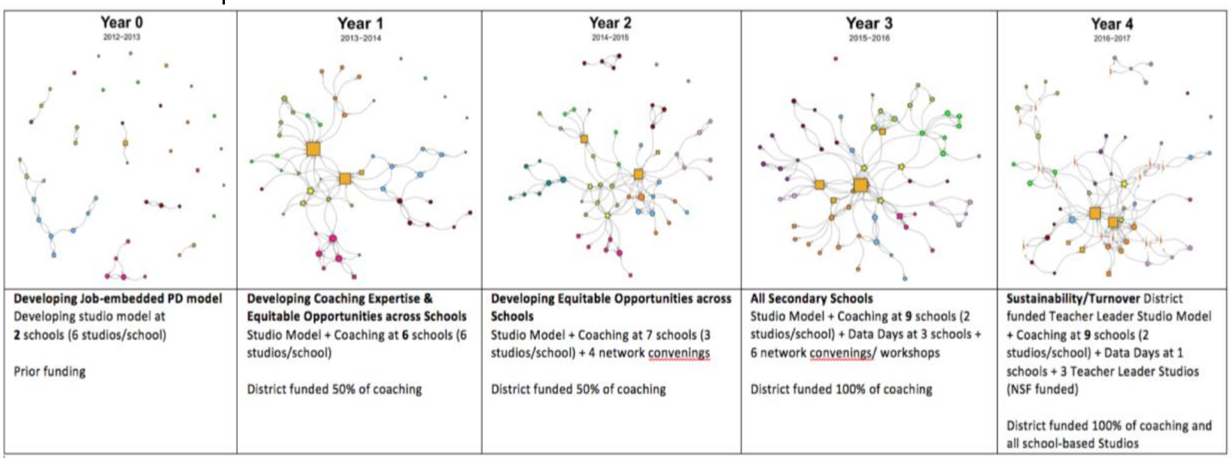

Figure 2. Sociograms of the network before, during, and after NSF funding

Furthermore, exponential random graph model (ERGM) statistical analyses of the NIC indicated that once a tie formed within the network, it persisted. Additionally, many of the professional learning opportunities developed with NSF funding are now fully funded by the district, such that school-based structures, coaching, and the development of a teacher leader cadre across schools continue. In short, multiple forms of professional capital and infrastructure cultivated during the previous project are enduring.

Application to SPS AST^{EE} NIC. One of our biggest regrets was not being able to track varied types of improvements that occurred over time, it took time to develop practical measures (Yeager, Bryk, Muhich, Hausman & Morales, 2013) that were sensitive to the changes being implemented. The NIC we are interested in developing for this project differs in three key ways: 1) we will have a strong set of measures sensitive to the development of the NIC at the outset of the project, 2) we will develop a NIC in a large district rather than mid-sized district (with 74 vs. 14 schools), and 3) we will focus on primarily on elementary (K-5) teaching and learning as a way to create ambitious and equitable learning opportunities early in students' schooling experiences.

***DRL-1417757:* Deep Learning Labs for SPS elementary science (2015-2017)**

While the proposed project draws on key learnings about NICs and the continual improvement of AST practices, it also builds on partnership work between the UW AST group and SPS elementary science specifically. The UW AST group has partnered with SPS on a number of small-scale projects over the past 12 years, but we began a deeper partnership with the Learning Labs project over the last few years. We developed and piloted a 10-week blended practice-based Learning Lab to support K-5 teacher learning and classroom integration of scientific modeling and argumentation, and partnered with SPS district specialists to co-facilitate in-person and on-line professional learning. We began by piloting the blended Lab with 14 teachers then opened enrollment. Approximately 330 K-5 teachers, and 30 teacher leaders stepped forward to participate in a broader-scale pilot. We maintained key components of the professional learning opportunities in the Lab (e.g., collaborative investigation of and iteration on AST practices and tools in classrooms, blended in-person and online support) while adapting for functionality across SPS. We developed a five-day summer teacher leadership academy in which we partnered with a culturally and linguistically diverse community center to team teach units with AST practices and tools. Teacher leaders then took the lead in making their learning public and supporting groups of their peers during in-person regional meetings with the 330 teachers.

Analyses of teachers' participation in the Lab pilots show teachers trying on, adapting, and sharing small grain-size practices and tools for ambitious and equitable science teaching provided; engaging in reform-oriented social interactions in their classrooms like asking probing questions to understand and extend students' ideas about phenomena; and collaborating in-person and online around problems of practice. Teachers from all SPS pilots named an emphasis on student thinking and adapting instruction in response as distinctive from what they typically discuss with colleagues:

> "I liked being able to share a student model that we all looked at, and really discuss what this student might be thinking, and share ideas of some lessons that might bring him to a deeper understanding… It's rare to have others 'see' what my students are thinking, and have collaboration on supporting their thinking" [end-of-Lab survey].

Several teachers also spontaneously began redesigning existing science units by organizing lessons around a puzzling phenomenon–demonstrating evidence of initial spread within their classrooms (Coburn, 2003). Data from a practical measure showed that a majority of K-5 teachers asked "back pocket questions" that pressed student thinking, and many publicly recorded students' ideas for their classes to work on together. Data also suggested areas of progress and areas for growth. Figure 2 shows teachers' reported use of AST tools. Between the first and second meetings, we saw a jump in teachers' use of tools for supporting students' sense-making about activities they did in class ("summary table/chart") and revising models as they progressed in units of instruction. This data also highlights an area where more concerted work is needed – supporting equitable talk opportunities in K-5 science classrooms (evidenced by the low use of structures like the "discussion stoplight" or "structured talk").

(Structured talk supports) (Summary table) (Grade 2 student model scaffold with revisions)

Figure 3. 2017 SPS teachers' reported tool use in K-5 science

We also piloted a student voice practical measure, adapted from Herrenkohl et al. (under review), to better understand students' perspectives on how they felt in science class and activities that helped them learn. Reporting on results from 98 students across five K-2 classrooms, the predominant emotions that students reported were "happily challenged" (62%), "excited" (50%), "interested" (42%), and like a "scientist" (42%). Some students reported feeling "confused" at times (20%), but few felt "frustrated" (9%). In terms of activities, students circled "made models" (75%), "made sense of observations" (73%), and "talked about ideas with classmates" (72%) as the top three activities that helped them learn, and several students specifically wrote that they liked making their own models or doing so with their classmates. These data, in addition to student artifacts we are collecting, suggest that students are engaging in forms of scientific practice that may be productively challenging them.

Application to SPS AST^{EE} NIC. In short, the degree and depth of momentum we are seeing from elementary teachers in SPS is promising; they are eager to participate in science PD that helps advance their teaching. We have made headway with 30 teacher leaders and 330 teachers with initial AST professional development. We have evidence that the district science department is adept at scaling PD to large numbers of teachers and that the partnership is highly capable of developing and adapting practical measures that provide feedback to teachers and to PLC leaders. Moreover, we are clear that moving forward we must focus efforts on: 1) providing equitable opportunities for teachers to learn new practices and opportunities to learn from one another as there are numerous pockets of practice innovation and expertise in supporting diverse learners across the system, especially within international schools, but no systematic mechanism for learning across the system, and 2) developing teacher leaders who can support on-going inquiry and innovation in the system. Developing a NIC that affords both localization of practice and system-wide learning holds promise for addressing these challenges. Our aim is to take what started as a 10-week program and expand it to a 3-year program that supports all 1200 elementary teachers in SPS and 74 principals (who have asked to be included in efforts moving forward).

Intellectual Merit

Learning in and from single-district NICs

This study draws on research about NICs, PLCs, teacher leadership, ambitious and equitable science instruction, and the notion of developing professional capital. The literature on NICs emphasizes the importance of improvement work at multiple levels in systems, which is particularly relevant for work within a singular district (Thompson et al., under review). In his theory of improvement systems, Engelbart (2003) suggested three levels of improvement are needed: 1) A-level on-the-ground work (which we equate to the improvement of ambitious and equitable instruction in classrooms), 2) B-level work that designs local arrangements and structures to improve A-level work (which we equate to the improvement work in regional PLCs), and 3) C-level trans-institutional work that generates capacity for learning across institutions (which we equate to the improvement of knowledge sharing across regions). Practically speaking, regional PLCs will begin with 20 schools, 3 schools/region in year 1 then grow to 12 schools/region by year 3. For the third year, picture 150-200 teachers gathering in groups in a lunchroom after school on an early-release day examining student work, designing tools to supplement curriculum with similar grade-level teachers, teacher leaders, researchers, content specialists, district science specialists and principals working with teams—and then commit to experiment with a tool and regathering a few months later to engage in another improvement cycle. Regional PLCs will meet 4x/year (this is the model we ran with the Learning Labs project, but for a 10-week period of time, and we started with 150 teachers in the lunch room rather than growing to this number).

While PLCs are important structures for knowledge-building, if they stay isolated their improvement will stagnate and the influence of their expertise stays limited (Jackson & Temperley, 2006). Much of the literature on educational reform (NICs and otherwise) tends to describe improvement work in classrooms and in PLCs (A and B levels), but there are far fewer descriptions of learning across PLCs (C-level) (Bryk et al., 2011). This project will contribute to our understanding of multi-leveled knowledge building within a single district, and with an all comers model--most NICs described in the literature develop across districts, so there is not a solid basis for understanding how NIC development impacts decisions about district infrastructure.

Below we describe three design principles that have/will inform the initial development of the SPS AST^{EE} NIC. First, we began by applying the principle of *mapping a complex problem from multiple perspectives and developing a common aim*. We developed an initial driver diagram (Figure 4)—a driver diagram is a NIC tool for articulating a working theory of improvement that includes causal language about how actions might support a particular end goal (Bryk et al., 2011). Through conversations with SPS teachers, district leaders, principals and educational researchers we decided that *a central aim is to focus on the improvement of all students' written and spoken scientific models, explanations and arguments, with a particular focus on equity in classroom teaching*. Each regional PLC (comprised of elementary teachers, a science coach, a science education researcher, school administrators) will develop and refine a related and more specific aim based on their interests and local contexts. The second design principle is *understanding variability in performance by using common practical measurements* as a central activity in the NIC (Yeager et al., 2013). At the outset of this study we will have a set of measures designed to provide feedback on the A, B and C levels of the NIC such that we can understand key questions of: *What works? Under which conditions? And For whom?* These questions will help us understand variability and inequities in the system. We have or will modify a set of practical measures that provide an easy-to-use gage for system improvements. Lastly, we will apply a third principle of *using common protocols for inquiry to support a continuous improvement ethic across the network*. Each PLC will have a similar professional learning structure composed of a similar set of research-practice partners and will meet quarterly with the goal of building strong learning cultures that engage in continual improvement (Horn, Garner, Kane & Brasel, 2017; Stoll, Bolam, McMahon, Wallace, & Thomas, 2006; Vescio, Ross, & Adams, 2008; Woodland, 2016), and that move beyond conversations about “sharing activities, information, and student anecdotes” (Nelson, Deuel, Slavit, and Kennedy, 2010, p. 176) and systematically pursue questions of learning goals and instructional practices, reason with student data, and connect general teaching principles and theoretical understandings to specific classroom instances (Feldman, 1996; Horn & Little, 2010; Slavit & Nelson, 2010). Teacher leaders (practicing teachers with strong classroom discourse practices who were selected by district science specialists and who participated as leads or teachers in the Learning Labs project) will be instrumental in the development of these PLC cultures, which means that a number of network activities will need to target and support the development of their facilitation practices such that teacher leaders can sustain a team’s inquiry stance, maintain a focus on student learning, and support group collaboration (Borko, Koellner & Jacobs, 2014; Cheung, Reinhardt, Stone & Little, 2018; Wenner & Campbell, 2017).

The NIC structure should help address issues of “equity of inclusion,” as we thoughtfully grow the NIC to support all 1200 elementary teachers in SPS. Historically the quality of instruction in SPS can depend on which end of Seattle students live in, with North-end schools having better access to material resources and partnerships and more prepared teachers. By building structures to support all teachers, and by networking teachers we hope to at least provide more equitable teacher learning opportunities in SPS. Moreover, it is a good time to focus on the improvement of instruction since, for the first time in 25 years, all K-5 teachers will have access to high-quality instructional materials in the fall of 2019.

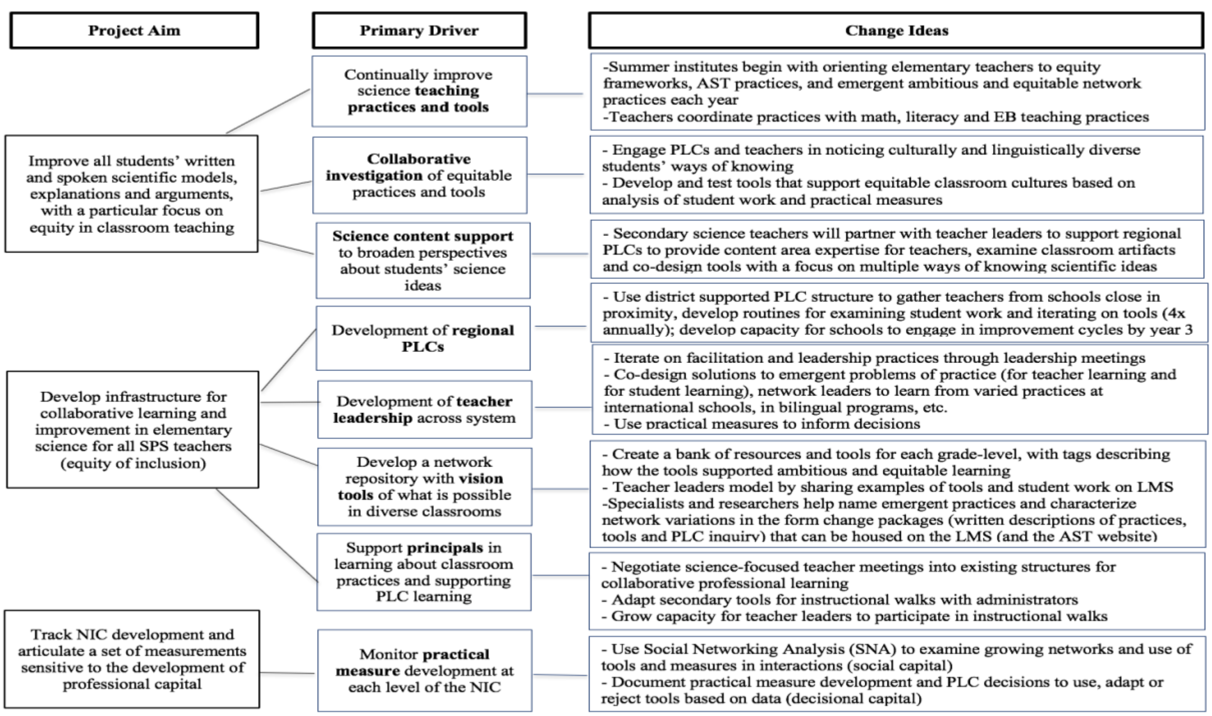

Figure 4. SPS AST^{EE} NIC Driver Diagram: Project Aims and Working Theory of Action

Improving Ambitious and Equitable Teaching

More than just providing access to materials and professional learning opportunities, it is also important that we orient the SPS AST^{EE} NIC to advance knowledge about ambitious and equitable K-5 science teaching practices that build on students’ funds of knowledge and their cultural and linguistic resources. We believe our prior research on AST practices is a good start toward supporting equitable classroom cultures that deepen students’ engagement in scientific ideas and practices (such as modeling and developing evidence-based explanations and arguments), but further work is needed. Building on cultural studies in education (Bang & Medin, 2010; Rosebery et al., 2015), we argue that providing rich opportunities for students to engage in scientific practices of scientific modeling, explanations and argumentation means empowering all students to actively build relationships with knowledge and with others—teachers and peer students (Cornelius & Herrenkohl, 2004). Below, we propose three modified AST instructional foci that have the potential to support equity in classrooms and that can be the object of study and improvement for each subsequent year of the project.

1) *Noticing students' cultural resources and experiences and using these to plan and adapt culturally relevant, place-based phenomena that are meaningful to children's lives (Year 1 emphasis)*

The AST practices begin with scientific modeling and inviting students to reason about and construct explanations of puzzling phenomena in the natural world (Windschitl, Thompson, & Braaten, 2018). Teachers use puzzling phenomena from the curriculum or they select their own phenomenon that they believe are relevant to students, such that science can be made accessible for students and encourage them to start from what they know. This process approximates relevance. In the first year of the project we plan to support PLCs in inquiring into strategies and tools that can help them learn about their students' and students families' connections to the content and to ways of doing science, and invite teachers to make modifications to the unit and to the model scaffold for the unit (see Figure 2, the model scaffold tool functions as an anchor for the unit as students revise this model in light of new evidence). PLCs will plan for and investigate how tools such as the model scaffold afford or constrain opportunities for students' to build on their funds of knowledge, and can refine practical measures that give them feedback from students (and potentially families). This way, we can honor students' emerging ideas and capabilities in the knowledge building processes of modeling (Lehrer & Schauble, 2006). Similarly, a few recent studies in mathematics education have argued that students develop a sense of agency by constructing and using mathematical models to analyze and act on important issues in their communities and lives (Greer, Verschaffel, & Mukhopadhyay, 2007; Hernandez-Martinez & Vos, 2018). Importantly, this year will also focus on expansive methods for noticing students' capabilities and diverse ways of communicating their ideas (gesturing, translanguaging) and explicitly work on developing asset-based (rather than deficit) perspectives about diverse students (Hand, Penuel, Gutiérrez, 2012; Suárez, 2018).

2) *Positioning students as active knowledge builders, encouraging students' collaboration and learning from one another in constructing models, explanations and arguments & supporting linguistically diverse students in classroom discourse. (Year 2 emphasis)*

The AST practices support students in making sense of activities, revising models and constructing evidence-based explanations and arguments, but do not explicitly support students in drawing on their linguistic resources. In SPS there are bilingual programs where students take science in a different language (Spanish, Mandarin, Japanese) and in many classrooms at least 20% of the students are emergent bilinguals (EBs). In our last NIC project we partnered with secondary teachers who had ELL endorsements and EB district specialists to develop discourse practices and classroom tools that blended AST practices with EB practices such that classrooms attended to metalinguistic knowledge and developed academic. For the second year of the project we want to support PLCs in developing discourse protocols and other tools that build on students linguistic resources. When teachers teach the language of scientific ways of thinking and then provide structured ways to practice using academic language in context all students can take an active role in building knowledge for themselves and their classroom communities (Schleppegrell, 2013; Lee & Buxton, 2013). By tapping into students' resources, we can encourage students' collaborative knowledge building by shaping productive epistemic discourses among students (Louca, Zacharia, & Constantinou, 2011; Williams & Clement, 2015) and build epistemic norms and cultures in classrooms (Berland et al., 2016). We will encourage PLCs to design and engage in cycles of inquiry with instructional strategies and tools to support linguistically diverse students—e.g., structuring talk opportunities, encouraging the use of home languages—and support PLCs in attending to how and what students learn in the process.

3) *Soliciting feedback from students about their learning and their experiences. (Year 3 emphasis)*

In our previous NSF-funded projects we designed practical measures in the form of exit tickets to solicit feedback from the most important members of the NIC: the students. We wanted their voices to be heard, and to provide teachers with feedback on how they were teaching. More than formatively assessing constructs learned we asked students to describe what they learned and how and why they participated/or not. To support students' meaningful participation in scientific practices, it is important to attend to how students understand the goals and meanings of the practices that they engage in (Berland et al., 2016). While we plan to provide exit tickets each year, in year 3 we will engage PLCs in developing and iterating on exit tickets as they seek to build productive epistemic cultures together with students.

PLCs can investigate how culturally and linguistically diverse students experience their classrooms and continue to refine planning and discourse tools (from years 1 and 2) based on this data.

As we seek to broaden perspectives about what counts as scientific ideas and ways of knowing science, we will engage a set of set of secondary science teachers to co-think about these issues and help elementary teachers sure up their content knowledge—such that they are primed to hear students' diverse experiences as valid scientific experiences to build on.

Through working on a set of common practices and tools, the NIC will be engaged in developing professional capital (Hargreaves & Fullan, 2012), which includes the development of "social capital" the collaborative power of role actors working together (which can be understood in part through SNA), and the development of "decisional capital," which refers to professional judgment and processes for making decisions. We will examine these forms of capital at multiple levels of the system.

Research and Development Design

Research Questions

For this study we are interested in examining how a NIC aimed at the development of ambitious and equitable teaching practices develops professional capital. There are three related questions, the first investigates what forms of capital develop, and the second two address how capital develops.

RQ1. How do elementary science instruction and student learning outcomes each advance within the developing NIC?

a. How does science teaching practice change -- for whom, and under what conditions?
b. How do student learning outcomes change -- for whom, and under what conditions?
c. How are changes in science teaching practice connected to changes in student learning outcomes?

RQ2. In what ways does decisional capital develop within the system? How do teachers and PLCs make decisions about establishing equitable K-5 classroom cultures? In what way do decisions get embedded in practices and tools? What influences decisions to use, modify, and spread tools and practices through the network?

RQ3. How does social capital develop within the system? Which social networks support teachers in shifting their practices? What kinds of infrastructure support social capital?

Approach to Implementation

Building on our working theory we plan to cultivate regional PLCs and networked improvement across the district via teacher leaders and intentional use of the district's LMS. Table 1 provides a summary of anticipated project activities and numbers by year.

Table 1. Project activities by year

	Year 1 (19-20)	**Year 2** (20-21)	**Year 3** (21-22)
Regional improvement (supporting classroom teaching)	Summer PD + quarterly regional PLC meetings (6 regions throughout SPS), integrating into existing designated PLC time for collaborative learning		
	Emphasis on scientific modeling and noticing students cultural connections/funds of knowledge	Emphasis on classroom science discourse and designing for diverse linguistic participation	Emphasis on formative assessment and learning from culturally and linguistically diverse students' perspectives
	400 teachers, 20 principals	+400 teachers (800 total), 40 principals	+400 teachers (1200 total), 74 principals
Leadership development within the NIC (supporting teacher and network learning)	Summer institutes + teacher leader meetings		
	Emphasis on pedagogy and facilitation	Emphasis on pedagogy and improvement cycles	Emphasis on differentiation for teacher learning
	36 teacher leaders total	+12 teacher leaders (48 total)	
Technological infrastructure (supporting	Cross-district grade-level groups		
	Infrastructure for sharing classroom examples and productive tool adaptations		

network learning)	Content support from high school content specialists

We conceptualize regional PLCs as communities of K-5 teachers, teacher leaders, high school content specialists, and elementary curriculum specialists working primarily within but at times across grade levels. Over time, we intend for these communities to persist and grow in both localized expertise and scale. To support persistence and continued improvement, we will focus on distinct but interrelated science teaching emphases each year (see Table 1 and description above). PLCs will engage in continual iteration as they layer different practice emphases on grade-level units of instruction, cultivating both unit-specific and more cross-cutting knowledge and decisional capital for ambitious and equitable science teaching for all learners, with a particular focus on culturally and linguistically diverse learners (which is not only a focus of this proposal, but also a part of SPS's strategic plan).

From a network perspective, teacher leader meetings and interactions on the LMS are the primary mechanisms for knowledge being shared across regional PLCs. Teacher leader institutes and meetings will focus partly on pedagogy (to elevate and cultivate expertise in ambitious and equitable elementary science teaching) and partly on various aspects of leadership, beginning with facilitation practices that support productive practice-based discussions among teachers (Cheung et al., 2018). We anticipate primarily working with teacher leaders we have already begun work with last year, and intentionally recruiting teacher leaders with expertise in language learning to build capacity in this area. The LMS will also serve as a way to share examples and productive tool adaptations across the district, contributing to visions of what is possible in and across diverse local contexts.

Research Plan

We will use a mixed methods approach to inform our research questions and test and iterate along the way.

Data Collection. We will regularly make use of key measures (see Table 2) as indicators of how the system is functioning and to test and improve specific change ideas and the working theory of action. As seen in Table 2, some measures will be collected network-wide, whereas others will be collected for select groups (e.g., teacher leaders, case study teachers and their colleagues at four schools intentionally selected to represent each region and a range of socioeconomic demographics in the district) to provide windows into critical contexts within the NIC. Some measures will be used during each curricular unit (short cycle improvement data) and others will be used annually to understand improvement over time (intermediate cycle improvement data). Part of our work will also involve developing additional measures in relation to emergent change ideas.

Table 2. Key project measures

Indicator Type	Description of Measure, Data Sources, and Analysis	Data Collection
Student learning (RQ1)	*Student models* (N=24 classrooms/year). As a part of the PD with PLCs, teachers will design model templates for each unit. We will collect model templates and examine students' initial and final models from case study teachers' classrooms, specifically investigating variation in student sense-making and development of argumentation, modeling, and explanation practices (Kang et al., 2016) and the extent to which students articulate funds of knowledge over time (annual measure). Similarly, all teachers will examine student models as a part of the PLC meetings, consider cultural and linguistic ways of showing what students know, and will hypothesize links between instruction and student learning (instructional unit measure) using Critical Friends Group protocols (Windschitl et al., 2012). In year 1 we will collaborate with teacher leaders to develop a rubric the network can use to assess improvement for scaffolding model-based learning for various demographics and different learning modalities (new practical measure).	Intermediate cycle Short cycle
	Student voice practical measure (N=24 classrooms/year). We will partner with teacher leaders to refine a practical measure (page 4) so that students can share their perspectives on participating in classroom discourse, and teachers can formatively assess learning of disciplinary core ideas and scientific practices (Thompson & Jackson, 2016). This will be made available to the network as a within unit improvement measure, but we will track data annually from case study teachers. In year 3, PLCs will engage in cycles of improvement with the practical measure (maintaining core features but testing items that provide feedback on students' cultural and linguistic resources).	Short cycle Intermediate cycle
	Pre-post unit tests (N=48 classrooms/year). SPS teachers teach 3 science units/year, which have pre/post assessments. We will examine student scores on pretests and posttests for curricular	Intermediate cycle

	units to assess content learning by grade level at four selected schools as well as examine correlations with instructional practices observed.	
	NGSS assessment (network-wide). For the next three years, 5th grade students in SPS will take an NGSS assessment. We will examine how schools improve over time, and see if there are school-level indicators that are correlated with improvement for culturally and linguistically diverse populations (e.g., school-level average network density).	Intermediate cycle
Instructional practice (RQ1 &RQ2)	*Teachers' retrospective self-assessments of practice* (N=400 to 1200 teachers/year). We will adapt and use a survey we developed in prior projects with indicators of ambitious and equitable instructional practices and trends in perceived growth.	Intermediate cycle
	Practical measures of teaching practice (N=400 to 1200 teachers/year). We will use a 5-question practical measure at each regional meeting to assess which practices and tools are being used and the extent to which they are being used. The project team and teacher leaders can use this data to reason with emerging problems of practice and improve activities for regional meetings.	Short cycle
	Observations of classroom teaching (N=48 classrooms/year). We will purposefully observe sense-making lessons at the end of a unit of instruction (for 3 units/year) for case study teachers and colleagues at our four selected schools. In the first year, we will refine a classroom observation protocol we have used for the past ten years in secondary contexts to be sensitive to variation in effective equity practices (Hand et al., 2012; Lee & Buxton, 2013; Schleppegrell, 2013).	Intermediate cycle
	Teacher leaders' practice (N=36 to 48 teacher leaders/year). Teacher leaders will upload tools to the LMS during each unit of instruction. While these tools support the network of teachers in examining practices, we will also assess the lead teachers' practices according to 1) whether they ask questions, 2) whether questions are primarily *leading* toward desired answers or *probing* the student's thinking (Franke et al., 2009), and 3) evidence of substantive focus on student thinking and equitable learning (e.g., Richards & Thompson, 2016; Sherin, Jacobs, & Phillip, 2011).	Short cycle
Professional discourse (RQ2)	*Interactions around practice* (network-wide). We will observe teachers' interactions at regional PLC meetings and on the LMS for evidence of engagement in problems of practice– specifying, theorizing and experimenting with practice (e.g., Bryk, et al., 2015; Horn & Little, 2010)—and their use of asset-based language when describing learning for culturally diverse students.	Short cycle
	Practical measures of PLC discourse (N=36 to 48 teacher leaders/year). From the above, we will develop a practical measure that teacher leaders will use to quickly summarize discourse at regional meetings and assess how conversations address problems of practice (with data, with theories of equitable student learning and with specification of practice and tool use, Bryk et al, 2015). The project team and teacher leaders can use this data to reason with emerging problems of practice and improve activities at regional meetings.	Short cycle
Social networking (RQ3)	*Social ties and tool use in interactions* (N=427 to 1281 participants/year). Each year we will ask all participants (teachers, administrators, district specialists, researchers) to complete a survey about their interactions in the network, specifying the kinds of professional activities they have engaged in and the tools they have used when interacting with one another.	Intermediate cycle
Online participation (RQ2)	*Online metrics* (network-wide). Based on past levels of participation, we estimate that about one-third of the community will actively participate in the online LMS. We will track number of total site visits, and top number and kinds of posts. We will also examine how tools move from region to region through the LMS.	Short cycle

In addition to these articulated measures, we plan to 1) video record teacher leader meetings and regular project team improvement meetings to document the project's improvement cycles and 2) audiorecord interviews with members of the project team, teacher leaders, and case study teachers to more deeply understand their experiences and participation in processes within the NIC.

Data Analysis. Data analysis will occur in three types of cycles annually, each of which will inform our aims and research questions, including: 1) short-cycle, real-time data analyses during monthly partnership meetings meant to facilitate quick action when the team (district leadership/specialists and researchers) is alerted to critical issues in the field (e.g., regional meeting notes indicating that more support is needed for teachers at a particular school or grade level); 2) short-cycle data analyses during quarterly partnership meetings meant to target needed revisions prior to the subsequent PLC meetings (e.g., classroom observation patterns or online LMS counts indicating that a particular practice requires formal PD training across all teachers or a new tool or practical measure needs to be developed and tested); and 3) intermediate-cycle data analyses occurring annually in the summers to understand how the network is developing and potential correlates of network development, using both quantitative and qualitative approaches (e.g., case study work with teacher leaders may inform specific PD tailored to leadership; social network analyses may reveal faster network development for certain grade levels or certain regions). This third type of cycle will also involve analyses of individual-level student learning outcomes disaggregated by race, SES, ELL status (i.e., pre-post unit assessments within the year) as well as school-level student learning outcomes (i.e., whether grade 5 NGSS assessment passing rates exhibit change after participation in the project). Below we detail our anticipated analyses for each of our research questions.

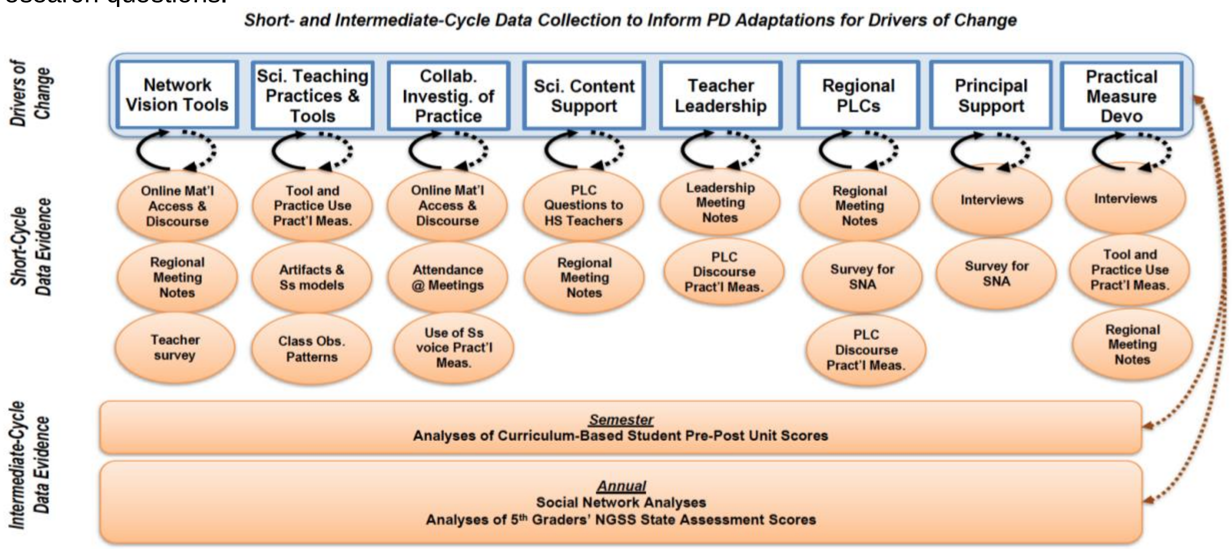

Figure 4. Data sources informing drivers and overall aims

RQ1 Analysis of instructional improvement and student learning. To address the first research question, we will describe patterned shifts in science teaching practice and seek to understand conditions that support improvement for all students including culturally and linguistically diverse students.

Teacher reports. We will use descriptive data from *practical measures* and *survey* data to generally understand how teachers are reporting improvements in teaching practices. We will examine this data by region and use this data to inform PLC activities (short cycle improvement). We will also use interview data from case study teachers to understand what influenced teachers' shifts in classroom practice. This data will inform subsequent surveys (intermediate cycle).

Classroom practice. We will use classroom observations to characterize how teachers are supporting the development of equitable classroom cultures. Qualitatively we will use ATLAS.ti to conduct content and discourse analyses of the participation of 24 case study teachers. All observations will be of teachers attempting sense-making conversations toward the end of unit of investigation, which means we will use cross-case comparisons (Yin, 2006) to understand variation in enactment and tool use (with a focus on model scaffolds, discourse protocols and exit tickets—which will be developed and iterated on in PLC meetings). We will use interview data to understand variation in planning practices and how teachers have engaged in iterative cycles of improvement (with their PLCs or individually). We will also examine connections between planning, enactment and reflection with patterns in pre- and post-samples of students' models. For example, in our project (DRL-1417757) we coded for differences in responsive teaching practices and revisions K-5 students made to their scientific models. We will share emergent patterns with teacher leaders and co-develop names for particular equity practices and indicators of improvement from student work. Once practices are named then we can better investigate how they equitably support participation by all students. In the past we have used this process at the secondary level to identify "foothold practices" that can be implemented daily, address issues of equitable talk/participation and rigor, contribute to alignment by reducing variation of small tests of practice across classrooms, and spread and spark development of more complex practices across the network (Thompson et al., under review). PLCs in our previous project (DRL-1315995) named and worked on five foothold practices, which we documented in the form of "change packages" (with prototypical sequences of the practices, exit tickets, and case studies of teams learning from inquiry). Change packages can inform intermediate improvement cycles for PLCs (and for new teachers entering the network) and the naming of practices can support quantitative analysis. We also developed practice trajectories for each practice so that we could evaluate the depth of the practice used during classroom observations. For this project, we anticipate developing trajectories for practices with network developed tools (model scaffolds for students, classroom discourse protocols, and exit tickets).

Quantitative analysis. We will quantitatively analyze *teaching practice data from classroom observations* of our sample of 48 teachers (two teachers per grade, K-5 grade levels) from four schools representing diverse socioeconomic demographics across regions. These analyses will occur annually using multilevel growth modeling with measurement occasions treated as Level 1 and teachers at Level 2; schools will be coded as fixed effects at the teacher level to evaluate school variation, as well as control for dependencies of teachers within schools. As we have done in previous projects, each teaching practice will be modeled separately, with Time coded to reflect the intervals between observations (we can test for linear and quadratic change over time with four measurements per year), and we will incorporate teacher-level covariates such as experience level and network-related characteristics to test for correlations with initial practice levels and change in levels over time. Missing data due to missing an observation here or there or attrition after two or more observations would be handled seamlessly using full information maximum likelihood estimation (FIML) procedures. *HLM 7* will be used for these analyses given its ability to employ FIML. (For multilevel modeling method details see for example Raudenbush & Bryk, 2002; Snijders & Bosker, 2012). Quantitative data from four schools' *student pre-post science unit assessments* (curriculum-based) will also be analyzed during the intermediate data analysis cycles for the same 48 teachers participating in observations. Because units will differ across grades, we will separate analyses by grade level; further, because some units may have different assessment scale lengths than others (e.g., 5 points vs. 10 points), we will standardize pre-post change scores using *z*-scores. Next, we will use multilevel modeling in which student scores are treated as Level 1, with three or four scores each across the year, and students and teachers at Levels 2 and 3 respectively (school controlled for analytically at the teacher level) to test whether we observe significant overall growth from pre- to post-unit across students for a given grade (the test of the intercept). Moreover, we can also test whether units significantly differ in student growth (categorically coded predictor set at Level 1), along with whether student- or teacher-level covariates are linked with growth. Again, *HLM 7* will be employed.

Another source of quantitative student science learning evidence will be *school-level fifth-grade NGSS assessment passing rates*: each year, all schools (not just the set of four participating in teacher observations) in the district will assess fifth-graders on science learning. These data will be available to us at the school-level in terms of percentage of students who met the benchmark criteria to "pass" the assessment. We can compare these rates for each school each year of the study relative to the year before study onset, adjusting for school-level poverty indicators (% of students enrolled in free or reduced lunch), using straightforward multiple linear regression. *SPSS 19* or *HLM 7* will be used for this.

RQ2 Analysis of decisional capital. The network is going to make decisions about equitable classroom teaching, and these decisions will get concretized as practices, tools and approaches to examining the content and substance of students' ideas. By design, we imagine sets of decisions will be made around three tools in particular: model scaffolds for students, classroom discourse protocols, and exit tickets. We will need to do a retrospective analysis of what emerges as salient around these tools then work backwards through PLC and network level data to trace how sets of decisions unfolded. We will be particularly interested in characterizing variation in the tools within the network and how teachers came to understand which tools worked to support equity, under which conditions and for whom. We will triangulate data from PLC meetings, PLC practical measures, and interviews to describe patterns in decisions and possible connections to patterns of social ties in the network.

RQ3 Analysis of social capital. To address the third research question about how forms of social capital develop in the network we will first employ probabilistic social network analysis modeling based on teacher surveys of who they collaborate with (as an indicator of social capital). Specifically, in Year 1, we will employ two exponential random graph models (ERGMs) to evaluate the likelihood of connections in the network given the network properties at fall (prior to PD) and spring (after one year of PD) (for ERGM details see for example Robins & Lusher, 2013; Snijders, Koskinen, & Schweinberger, 2010). The data for such models are taken from what are called "adjacency" matrices (structured as people-by-people nomination matrices rather than people-by-variables typically seen in traditional analyses). As part of these models, we will incorporate teacher-linked covariates that include teachers' school membership (categorically effect coded), science teaching experience (standardized), and whether the teacher is serving as a teacher leader (binary variable that would be effect coded). From this we could predict the 1) the probability of another tie (i.e., connection between teachers) forming in the network, and 2) whether important covariates are predictive of tie formation. ERGMs will be conducted in *R*'s statnet suite of packages, along with network descriptive statistics and sociograms to aid in understanding model estimates. We will also employ *separable temporal exponential random graph modeling* (STERGM; see for example Krivitsky & Handcock, 2014) to better understand the spring network's state (after participation in the project) by incorporating the prior fall network information. This model would be able to estimate tie (social connection) formation as well as *tie persistence*, including tests of covariates for both tie formation and persistence. STERGMs, like ERGMs, would be conducted in *R*'s statnet suite of packages. In Years 2 and 3 the same modeling techniques -- using ERGMs for individual timepoints and STERGMs for determining network persistence over time -- will also be applied to survey data collected in the spring of each project year. Missing data in the STERGMs due to teachers moving in or out of the district during the project would be handled by using teachers' auxiliary information from prior or subsequent time point data to avoid removing cases from analysis. From previous projects we have seen that once teachers make ties, they are likely to maintain them within and across schools, which is an indicator of sustainability.

To investigate the role of infrastructure we will examine how the project gradually integrates with existing district structures, namely with early release time, the district's LMS, and principal involvement. We will examine teacher surveys and interviews with district staff and teachers to assess how prepared the system is to sustain the professional learning infrastructure and the degree to which policy shifts have occurred. Sociograms will also help district staff determine if the teacher leaders they selected are well-positioned to continue to lead regional or school-level PLCs after the grant.

Purposefully designing a NIC fundamentally assumes that social networking is a part of the professional learning design, along with tools and activities that support robust forms of teacher learning (such as analyzing student work and developing tools to support all learners). This means that we will use SNA not as a way to measure networks of friendships or convenience, but rather as an indicator of networked improvement. Methodologically, what is innovative in this project is the use of: 1) social networking as professional learning support for the adaptation and improvement of practices and tools, rather than traditional models of PD designed for adoption and dissemination without network support, 2) a systems approach to data collection and analysis, rather than traditional structural approaches like studying one part of the system, and 3) probabilistic social network analysis to estimate the significance of network parameters alongside the development of teaching practices.

Dissemination

Researchers at the University of Washington have high capacity for disseminating research findings to varied audiences. To share insights about instructional practices/tools and principled improvement work with teachers and broader educational systems, we use the following mechanisms: resources that we make available through the UW AST website, short publicly-accessible briefs written for STEM Teaching Tools, practitioner articles co-authored by teachers and researchers (e.g., Shim, Thompson, Richards & Vaa, 2018), and existing partnerships with a variety of networks and organizations (e.g., regional networks and Educational Service Districts in Washington, membership in 100Kin10 with 230+ partners aiming to improve STEM teaching, NSTA and NSELA).

We intend to disseminate results to researchers through publications in journals such as the *American Educational Research Journal, Science Education, Journal of Teacher Education, Journal of the Learning Sciences, Educational Researcher*, etc. We will also present findings at conferences like AERA and at NSF annual meetings. The College of Education at the UW has a dynamic communications office that regularly translates publications and presentations into news briefs for broader reach.

Expertise and Mechanisms to Assess Success

Project Team

Jessica Thompson (PI) is an Associate Professor in Curriculum & Instruction at the University of Washington and brings 12 years of experience engaging in research-practice partnerships and building and studying NICs within and across school districts. She has authored several articles and books around ambitious and equitable teaching, teacher learning, and tools and routines that support the development of teaching. Dr. Thompson has expertise in facilitating and studying teacher learning of ambitious science teaching practices at the elementary and secondary level, as well as expertise in the methods of improvement science. The regional and district-specific NICs she has cultivated share a common vision of high-quality instruction and sets of instructional practices and tools that ground learning and improvement. With local and NSF funding, she has supported over 900 teachers, teacher leaders, principals, and specialists to date. Dr. Thompson will oversee all aspects of the project's implementation and improvement work at the University of Washington, partner in the refinement of practical measures and iteration on the systemic approach, and co-facilitate teacher leader meetings with SPS Specialists.

Elizabeth Sanders (co-PI) is an Associate Professor in Measurement & Statistics at the University of Washington. She has served as quantitative methodologist on numerous federally funded projects, including a recent NSF grant (DRL-1315995) with Dr. Thompson modeling the heterogeneity of science teaching practices in response to innovative networked professional development treatment. She has specific expertise in modeling methods linking teaching practices to student outcomes, including for one NSF grant on links between high school science teaching of bio-informatics ethics and students' career awareness (published in *Cell Biology Education*), three IES and NIH grants linking upper elementary school teachers' literacy instruction and student outcomes (published in *Journal of Research on Educational Effectiveness*, *Reading & Writing*, and *Scientific Studies of Reading*), and one IES grant linking a school-wide K-8 behavior program to student outcomes (published in *Exceptional Children* and *Behavior Disorders*). For the proposed project, she will develop and support the project's quantitative infrastructure and conduct analyses of the developing network as well as connections among network indices and other project measures.

MaryMargaret Welch (co-PI) is the PK-12 Science Program Manager for Seattle Public Schools. She has extensive experience as a K-12 science educator, curriculum leader, and school and district-level administrator, and brings in-depth understanding of the context and history of science instruction in SPS. She has been recognized for her excellence in teaching with several awards including Puget Sound ESD Teacher of the Year, 3 times Mercer Island School District Teacher of the Year, Washington State Outstanding Biology Teacher, and others. Ms. Welch has served as a PI for several research-practice partnerships, including the NSF-funded Carbon TIME grant with Dr. Andy Anderson at Michigan State University and the MSP PSEP grant with Dr. Philip Bell at the UW, through which she has co-presented at national conferences and contributed to disseminated resources for educators. Ms. Welch is also the Seattle co-founder of the SEAVURIA project, a global partnership to empower students with STEM skills and practices to be agents of change and champions of social justice. Ms. Welch will oversee all aspects of SPS' implementation and improvement work, coordinate summer institutes, and play an integral role conceptualizing and implementing systemic iterations based on discussions at project team meetings.

The core project team will also include three Elementary Science Specialists in SPS and one Research Assistant and one Research Associate at the UW. SPS Specialists will have primary responsibility for developing professional learning materials and overseeing posting on the district LMS. They will also co-facilitate teacher leader meetings, and conduct classroom observations in conjunction with UW Research Assistants, who will have primary responsibility for data collection in the field. SPS Specialists and UW Research Assistants will participate in project team improvement meetings. The team will also include an UW AST postdoctoral research associate, she will have primary responsibility for coordinating data collection/analysis and overall project management, facilitating and documenting regular project team improvement meetings, and co-facilitating teacher leader meetings.

Advisory Board

We will have six advisory board members who we will consult with regularly to provide external review and feedback. At the start of the project, the project team will meet with the advisory board in a virtual half-day meeting to get initial feedback on our 1) working theory for and approach to implementation and improvement and 2) plan for engaging in and documenting iterative research cycles. We will then meet annually to review findings from intermediate cycles and seek feedback on problems of practice. Additionally, we will reach out regularly to individual advisory board members given their particular area of expertise and how it connects to this project (i.e. the development of the RPP and NIC, the development of practical measures, the structure of the teacher leader cadre, the degree to which practices and tools address issues of equity for culturally and linguistically diverse students). In line with our emphasis on documentation and process monitoring, we will keep track of issues and data discussed and change ideas proposed at our advisory board meetings. Learnings with advisors will not only be included in annual reports to NSF, but will be an integral part of the improvement work and incorporated in papers and other forms of reporting from this project.

Philip Bell is a Professor of the Learning Sciences & Human Development at the University of Washington. He is executive director of the UW Institute for Science & Math Education focused on equity-focused innovation in K-12 STEM education, and he is co-director of the Learning in Informal and Formal Environments (LIFE) Science of Learning Center. He pursues a cognitive and cultural program of research across diverse environments focused on how people learn in ways that are personally consequential to them and has studied scaled implementation of educational improvement. He served as a member of the Board on Science Education with the National Academy of Sciences, co-chaired the National Research Council consensus report effort on Learning Science in Informal Environments and served on the committee of the NRC Framework for K-12 Science Education that was used to guide development of Next Generation Science Standards. Dr. Bell is also developing STEM Teaching Tools for equity-focused improvements in science education.

Hilda Borko is a Professor at Stanford with expertise in factors that facilitate and hinder teachers' learning of reform-based practices, and in policies and practices that can support teacher change. She studies the impact professional development programs for middle school mathematics teachers on teachers' professional communities and their knowledge, beliefs, and instructional practices and has expertise developing practical measures.

Paul Cobb is a Professor of Teaching and Learning at Vanderbilt and has expertise in developing networks that support equitable mathematics instruction, particularly through supporting district offices and principals. Over the past 10 years he has spearheaded the MIST (Middle-school Mathematics and the Institutional Setting of Teaching) project with similar lines of questions about networked improvement communities with coaches and principals supporting teacher learning, and structures that support equitable outcomes for African American students and English Language Learners. He has also conducted a study about RPPs, investigating our previous project in comparison with other RPPs.

Savitha Moorthy is the Director of STEM Equity Research at Digital Promise. Her work focuses on science and mathematics education, particularly on the design and implementation of programs, policies and practices that improve learning experiences and outcomes for all students. Ongoing projects include a research-practice partnership with the Clark County School District and in Las Vegas, NV, and a multi-stakeholder collaboration with the San Francisco Unified School District, both focused on improving science instruction for ELLs. She is a proponent of design-based thinking and her research-practice partnerships are grounded in Design-Based Implementation Research (DBIR), an approach that involves collaborating with stakeholders to identify problems of practice, address them through iterative, collaborative design, and develop strategies for sustainability and change. Equity is a central theme in Dr. Moorthy's work as her projects address the needs of educationally disenfranchised populations, including low-income families, ELLs, and students and teachers in diverse, urban school districts.

Manka Varghese holds a Ph.D. in Educational Linguistics and is an Associate Professor in the College of Education at the UW, where she teaches bilingual, ESL and teacher-education-related classes and is part of the ELTEP faculty. Her scholarship focuses on teacher education for multilingual students and improving pathways for multilingual students from K-12 schools to postsecondary education. Her work has appeared in Teachers College Record, TESOL Quarterly, International Journal of Bilingual Education and Bilingualism, Journal of Teacher Education, and she has published several book chapters. She is PI on a partnership project with SPS; Project PIMSELA is an IES funded collaborative policy-oriented partnership committed to understanding factors that can explain English learner (EL) students' diminished access to, and underachievement in math and science.

Carla Zembal-Saul is a Professor of Science Education at The Pennsylvania State University. She holds the Kahn endowed professorship in STEM Education for her research and practice as a scholar and teacher educator. Her research investigates teacher learning and development of instructional approaches and resources for supporting young children's participation in scientific discourse and practices. Zembal-Saul has been involved in school-university partnership work for most of her career, and her research takes place in these settings. The purposeful use of technology tools has played a central role in her teaching and research. In particular, Zembal-Saul has developed online video-based cases of science teaching practices, used video analysis tools with preservice and practicing teachers, examined the use of software scaffolds to support meaningful science learning, and implemented electronic teaching portfolios in teacher education. She is currently the project director for a national professional development grant working with teachers to co-design resources for creating equitable and inclusive opportunities for emergent bilingual children to develop language and participate in scientific practices in generative ways that build on children's funds of knowledge.

Attachment C: DRK 12 Driver Program

Project Aim: Improve all students' written and spoken scientific models, explanations and arguments, with a particular focus on equity in classroom teaching

Primary Driver	Change Ideas
Continually improve science **teaching practices and tools**	-Summer institutes begin with orienting elementary teachers to equity frameworks, AST practices, and emergent ambitious and equitable network practices each year -Teachers coordinate practices with math, literacy and EB teaching practices
Collaborative investigation of equitable practices and tools	- Engage PLCs and teachers in noticing culturally and linguistically diverse students' ways of knowing - Develop and test tools that support equitable classroom cultures based on analysis of student work and practical measures
Science content support to broaden perspectives about students' science ideas	- Secondary science teachers will partner with teacher leaders to support regional PLCs to provide content area expertise for teachers, examine classroom artifacts and co-design tools with a focus on multiple ways of knowing scientific ideas

Project Aim: Develop infrastructure for collaborative learning and improvement in elementary science for all SPS teachers (equity of inclusion)

Primary Driver	Change Ideas
Development of **teacher leadership** across system	- Iterate on facilitation and leadership practices through leadership meetings - Co-design solutions to emergent problems of practice (for teacher learning and for student learning), network leaders to learn from varied practices at international schools, in bilingual programs, etc. - Use practical measures to inform decisions
Develop a network repository with **vision tools** of what is possible in diverse classrooms	- Create a bank of resources and tools for each grade-level, with tags describing how the tools supported ambitious and equitable learning - Teacher leaders model by sharing examples of tools and student work on LMS -Specialists and researchers help name emergent practices and characterize network variations in the form change packages (written descriptions of practices, tools and PLC inquiry) that can be housed on the LMS (and the AST website)
Support **principals** in learning about classroom practices and supporting PLC learning	- Negotiate science-focused teacher meetings into existing structures for collaborative professional learning - Adapt secondary tools for instructional walks with administrators - Grow capacity for teacher leaders to participate in instructional walks

Project Aim: Track NIC development and articulate a set of measurements sensitive to the development of professional capital

Monitor **practical measure** development at each level of the NIC	- Use Social Networking Analysis (SNA) to examine growing networks and use of tools and measures in interactions (social capital) - Document practical measure development and PLC decisions to use, adapt or reject tools based on data (decisional capital)