THE NATIONAL CENTER ON SCALING UP EFFECTIVE SCHOOLS

Applying a Scale Research Framework to an NSF Math Science Partnership Grant

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Conference Paper
October 2015

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The National Center on Scaling Up Effective Schools (NCSU) is a national research and development center that focuses on identifying the combination of essential components and the programs, practices, processes and policies that make some high schools in large urban districts particularly effective with low income students, minority students, and English language learners. The Center's goal is to develop, implement, and test new processes that other districts will be able to use to scale up effective practices within the context of their own goals and unique circumstances. Led by Vanderbilt University's Peabody College, our partners include The University of North Carolina at Chapel Hill, Florida State University, the University of Wisconsin-Madison, Georgia State University, the University of California, Riverside, and the Education Development Center.

This paper was presented at NCSU's second national conference, Using Continuous Improvement to Integrating Design, Implementation, and Scale Up. The conference was held on October 7-9, 2015 in Nashville, TN. The authors are:

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This research was conducted with funding from the Institute of Education Sciences (R305C10023). The opinions expressed in this article are those of the authors and do not necessarily represent the views of the sponsor or the National Center on Scaling Up Effective Schools.

This paper describes the first two years of a five-year study of the scaling-up of citizen science curriculum modules for middle grades. The modules are co-developed by teacher leaders and research scientists and are intended to enable classrooms across North Carolina to collaborate with the scientists on cutting edge research through data collection, analysis, and digital communication. Applying scale research frameworks, we lay groundwork for studying the scaling-up of both the module development process and the process by which the modules are transferred to other teachers for classroom use. We use a design-based implementation research approach, facilitating cycles of planning and implementation by the project partners, and apply social network analysis in this initial phase.

INTRODUCTION

The overarching goal of the *Students Discover* project, a NSF-funded Math Science Partnership (MSP) grant (NSF Award ID# 1319293), is to improve STEM education in middle schools by developing a model for engaging students in doing real science. Project activities aim to create a context for student engagement in real, on-going scientific research by making citizen science projects accessible and tailored to the formal classroom environment. These citizen science curriculum modules include activities for data collection and analysis and they aim to establish a framework for teachers and students to pursue their own locally-generated research questions.

To develop, implement, and sustain the use of these modules in classrooms the Students Discover project partners are attempting a novel approach. They are bringing together teachers, scientists, district leaders, and other institutional partners to co-design the implementation process. This collaborative development process is intended to lead to sustained changes in teachers' content knowledge and instructional practice. Long-term project goals also include: increased student enrollment in advanced STEM courses; improved science achievement; better models for engaging citizens and underserved youth in citizen science; better models for collaboration with schools and the broader community; and institutional change at the partner organizations including the university, museum, and school districts. The research team is applying scale research frameworks (Coburn, 2003; Dede, Rockman, & Knox, 2007) to identify contextual variations where the innovations are implemented and examine processes for adapting the innovations under varying circumstances. The Students Discover project is currently nearing the end of the second of five years of funding.

In North Carolina 39% of 8th grade students report that they "never or hardly ever" design a science experiment, and another 29% of 8th grade students report doing hands-on science activities only once or twice a month (National Center for Education Statistics, 2011). The norm in science education has been a focus on traditional teaching methods – e.g. lecture, textbooks, and cookbook laboratory experiments with an emphasis on memorization and recall of facts. At the same time, there has been a long-standing call for education reform that emphasizes inquiry-based methods in science classrooms (National Research Council, 2012; Trautmann, Shirk, & Krasny, 2012). A growing body of evidence suggests that inquiry-based instruction rooted in the nature of science results in significantly higher student achievement with respect to content knowledge, reasoning, and argumentation skills (Wilson, Taylor, Kowalski, & Carlson, 2010; President's Council of Advisors on Science and Technology, 2012). The Students Discover project focuses on this persistent problem of improving science instruction in middle school classrooms.

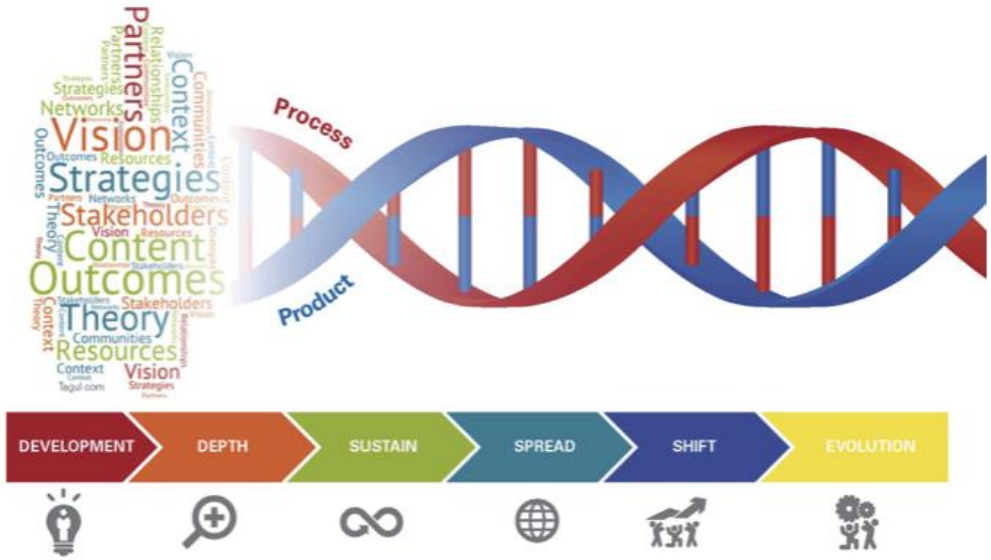
FOCUS AND PURPOSE OF SCALE RESEARCH

One of the greatest challenges of educational improvement is the difficulty of scaling up locally successful innovations to a wide variety of settings while maintaining the effectiveness, affordability, and sustainability of the innovation (Dede, 2005). Taking a successful initiative to scale is a complex, multidimensional endeavor that requires more than simply increasing the number of teachers, schools, and districts involved (Coburn, 2003). Innovations need to be flexible enough to allow for variation in context and implementation. It is critical, therefore, not only to understand "what works," but to address the more complex questions of "what works, when, and how?" (Means & Penuel, 2005).

The purpose of our scale research is two-fold (see Figure 1): development and scale. Through the fall of 2015 the research project has examined the collaborative *processes* by which teachers, scientists, and other project partners co-developed, implemented, and refined the citizen science curriculum modules and the framework for engaging students in "real science." Hereafter, we refer to these collective development processes as "Innovation 1." Moving forward, our scale research will seek to explore the curriculum modules and the framework for engaging students in authentic science that result from the partnerships between school district staff and professional development providers. The research will be guided by a set of incremental questions investigating the extent to which the curriculum modules and the framework for engaging students in authentic science can be scaled. Hereafter, we refer this scaling process as "Innovation 2."

Importantly, within the research on Innovations 1 and 2, we attend not only to the modules and framework being developed, but also to the development of systems of support to sustain their use (Fishman, Penuel, Allen, Cheng, & Sabelli, 2012). This focus on both the product and process for use is a foundational tenet of design-based implementation research (DBIR); through our work thus far we have come to understand that this focus is also a critical aspect of scale research. As we study these two innovations and the partnerships that create them, we are seeking to inform the development of an effective, scalable model for inter-institutional partnerships that increases student participation in authentic science and improve STEM education.

Figure 1. Foci and purpose of scale research



While substantial resources are devoted each year to research-based educational improvement, often the insights from many successful initiatives remain invisible outside of the scholarly community (Sabelli & Dede, 2001). Means and Penuel (2005) emphasize that most innovations, if they are designed to affect instruction in a wide range of contexts, need to be adaptable to varying conditions. They add that, given a program with this type of purposefully flexible design, the standard "fidelity of implementation" research and evaluation may not be appropriate. Simply determining "one overall effect size does not allow policymakers to determine the likely effectiveness of transferring the innovation to their local setting where students, teachers, and resources may vary from the conditions for success of the innovation, ideal conditions under which its effect size was calculated" (Clarke & Dede, 2009, p. 33). Context and enactment data provide program designers with valuable information on how to modify components of the innovation to achieve positive outcomes in a variety of settings (Fishman, Penuel, & Yamaguchi, 2006; Means & Penuel, 2005).

Using a scale research framework (Clarke & Dede, 2009), we are examining the processes for moving the innovations from their ideal "greenhouse" settings to environments where conditions for success may be less favorable. With an emphasis on design for sustainability and scalability (Clarke & Dede, 2009), our research is attempting to identify contextual variations in which the curriculum modules are implemented and in which the partnerships operate. We will also investigate the ways in which the innovations are necessarily adapted to these changing conditions. Identifying the variables that represent important conditions for success and measuring the impact their presence, or lack thereof, has on this success can enable prospective adopters of the innovations to better determine of the level of effectiveness they are likely to achieve (Clarke & Dede, 2009).

SCALE RESEARCH APPROACH: EXAMINING SYSTEMS AND SUBSYSTEMS

The Students Discover project is a collaboration between scientists at the Department of Biology at North Carolina State University (NCSU); the Nature Research Center at the North Carolina Museum of Natural Sciences[1] (NCMNS); The Kenan Fellows Program[2] (KFP); The Science House[3] (TSH); The Friday Institute for Educational Innovation (FI); seven North Carolina School Districts; and GrantProse Inc., the external evaluator for the project. As the scale researchers we are part of the "ecology of supports" (Fishman, Penuel, Allen, Cheng, & Sabelli, 2012) that help build the capacity of the "system" and "subsystems" of these inter-institutional partners. Achieving scalable innovations requires developing the capacity of the

[1] The North Carolina Museum of Natural Sciences is the state's flagship science museum, the largest of its kind in the southeast, and specializes in outreach engagement with the public.
[2] The Kenan Fellows Program is year-long fellowship for exceptional teachers in which they participate in a 5-week long internship in a local STEM industry, receive high quality professional development and leadership training, and present to colleagues around the state.
[3] The Science House delivers of high quality professional development and curriculum training for STEM teachers across North Carolina, empowering educators to integrate innovative STEM content, research, and technologies into their practices.

entire system to implement, scale, and sustain them. Furthermore, maximizing the functioning of each subsystem without working to develop the interconnections of the larger system can actually reduce effectiveness; this happens because the subsystem parts increasingly diverge from the larger whole.

In this paper we first tell the story of struggles faced by the Students Discover project partners – the larger system – during the first two years of the project. We also describe the strategies implemented by the scale research team to mitigate those challenges. We then examine two sub-systems within the project partnership: (1) teachers and scientists at the museum working together to co-develop and implement citizen science curriculum modules, and (2) the same teachers and a professional development provider developing and delivering training on the curriculum modules to teachers who were not involved in the project. Applying a scale framework we identify support factors and challenges for the work of the partners.

Scale Research Methods

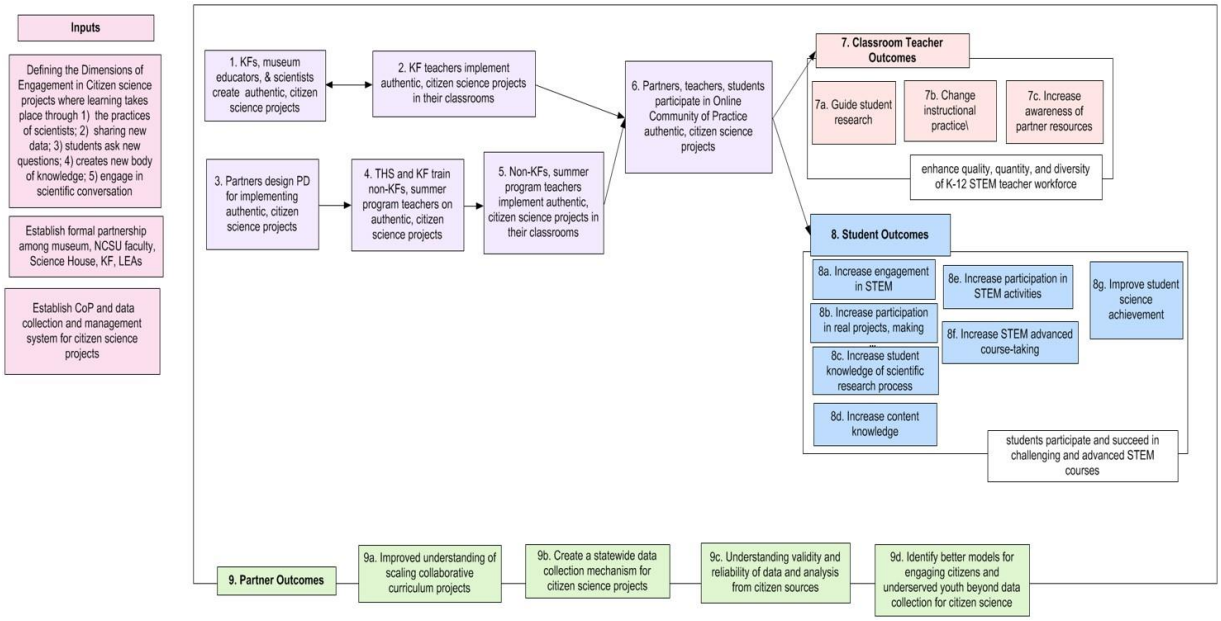
Throughout the study we have been using a DBIR approach (Fishman, Penuel, Allen, Cheng, & Sabelli, 2013) to address the questions of "what works where, when, how, and for whom?" Answering the many questions and sub-questions raised by DBIR requires a wide range of research methods (Penuel, Fishman, Cheng, & Sabelli, 2011). Using observations, interviews, and focus groups, the scale research team has been gathering data to understand the support factors and challenges related to the processes and products of Innovations 1 and 2. In later research phases the data will be used to inform the development of scale surveys. Analysis of the quantitative data from these teacher- and student-scale surveys and other evaluative, impact-focused data will also provide descriptive statistics and enable comparison of subgroups over time. The surveys will also help to identify varying contexts in which the innovation is

implemented and the necessary adaptations made by users. We are using social network analysis to capture the multilevel nature of teacher collaboration and to understand the role of formal and informal teacher interactions that may support or constrain changes to teachers practice (Penuel, Riel, Krasue, & Frank, 2009; Daly, 2010). This approach enables us to investigate patterns of interpersonal and intra-organizational relationships in which teachers' individual behaviors are nested (Moolenaar, 2012).

The Partnership System: Early Work

At the project's inception partners began with a basic, common understanding of the project's design and outcomes, as depicted in the project logic model below (Figure 2). Three KFP teachers (Kenan Fellows) from partner school districts are matched with a single scientist at the NCMNS. During a summer internship the three Fellows work side-by-side with the scientist, learning about the scientists' work and co-developing curriculum modules. This process takes place each summer for the first three years of the grant, with 12 new Fellows joining the four scientists every summer. Through this collaborative partnership teachers deepen their understanding of scientific research and scientists would increase their understanding of classroom contexts. After developing and piloting the Students Discover modules in their own classrooms during the following school year, Kenan Fellows and scientists revise the modules for continued use in subsequent years of the project. In collaboration with TSH and NCMNS educators, Kenan Fellows and the scientists then engage in a process of refining the citizen science lessons for adaptability in various classroom settings. Finally, through three-day summer workshops at the NCMNS and other regional workshops, TSH provides training and support for teachers across North Carolina to implement the modules in their classrooms.

Figure 2. Students Discover Logic Model



With this common understanding of the general goals and strategies of the project, in fall 2013 each partner began semi-autonomous work on activities related to their role. The NCMNS hired post-doctoral scientists for each of the four labs at the museum. The KFP recruited and selected teachers for the first one-year fellowship with the project. Through its "Your Wild Life" program the NCSU Department of Biology continued to develop online resources for existing citizen science projects, and promoted citizen science more generally through its network of educators around the world. TSH began conceptualizing a professional development approach for training teachers on the Students Discover citizen science modules. The FI research team further developed its scale research plan. School district partners waited in the wings for the project to get off the ground.

As project partners proceeded with implementation, challenges began to emerge. The KFP faced challenges in recruiting and selecting teachers for a summer internship that was only vaguely defined – with few details about the labs' research, the KFP could not reliably place each teacher in a lab researching content aligned to the teacher's grade-level and subject area

standards. The newly hired scientists, unfamiliar with middle school content, contexts, and curricular standards, struggled to conceptualize internships that met the needs of the teachers while also meeting their own needs to conduct cutting-edge scientific research and publish findings. During the early months of the project, as other partners began aligning their work to the goals of Students Discover, confusion began to swell over important details of the project and tensions emerged.

Identifying Partnership System Challenges

Through informal observations during monthly Students Discover project meetings and individual interviews with project leadership, the scale research team began identifying and documenting challenges that were impacting the health of the overall system: sporadic and inconsistent communication among project partners; lack of clarity on partner roles; competing definitions of "citizen science"; differing conceptualizations of "scale"; and tensions between partner priorities. These challenges were characteristic of large-scale endeavors with multiple partners, and similar to other NSF MSP grants.

Communication. Effective communication was the most difficult challenge for the project partners. During the early months of Students Discover the communication flow among project partners was sporadic and inconsistent. Our research results indicate that project partners intermittently communicated with each other in response to issues as they surfaced, rather than continuously communicating with each other in a proactive way to anticipate and prevent shortfalls. Findings also suggest that different partners received different messages at different times and had different strategies for communicating. Some partners, such as the school district teams, felt left out of the communication loop altogether. Communication among project partners

was made more difficult by the varying norms, tools, and languages of the subcultures in which the partners operated.

Lack of clarity regarding partner roles. Related to the communication challenges, our interview results show that not all partners fully understood their own roles and the roles of other partners on the project. This lack of clarity regarding roles and responsibilities led to confusion over lines of authority and the extent to which each partner had autonomy to make decisions. Furthermore, the findings suggest that Students Discover partners did not always understand the functions each person individually played within their home organizations. This led to additional confusion about staff supervision and management responsibilities.

Competing definitions of "citizen science." Findings from our observations of project meetings and interviews indicate that members of project partner teams frequently struggled to conceptualize the definition of "citizen science" and its core components. This had implications for the broader work of the project, since one of the primary goals of the entire project is the production of high quality citizen science curriculum modules. For example, if a core component of citizen science is a central repository for data submission that can then be accessed and used by a broader audience for hypothesis generation and analysis, what did that mean for the Students Discover labs at the museum that did not yet have an online repository? For projects and labs without a central data repository, was their work citizen science, or were the activities examples of hands-on authentic science but not citizen science?

Different conceptualizations of "scale." While most partners understood that "scaling the innovation" was a goal of the project, our findings suggest that there was confusion over what was being scaled, who was scaling it, and how it would be scaled. For many project partners outside of the scale research team "scaling the project" meant simply increasing the number of

teachers who used the Students Discover curriculum modules in their classrooms. Even among our own research team, articulating the two innovations that would be the focus of our scale work only occurred through long meetings of hard thinking for scale team members.

Tensions between partner priorities. While all partners entered the project with the same overarching goal of improving STEM education in middle schools through the use of citizen science, tensions emerged due to the competing priorities of the various partner organizations. For example, results from observations and informal interviews revealed that the post-doctoral scientists felt a constant demand to publish and build their research experience and curriculum vitae. At the same time, the KFP was focused on ensuring that the internship in the scientists' labs provided high quality professional development opportunities for the teachers. Many members of the project partner teams were excited about the idea of having students participate in cutting edge research, for example, but were ignorant of the challenges to this posed by the parameters within which formal schooling takes place. The Fellows struggled with balancing the educational goals of Students Discover lessons with the educational goals of their schools, which often focused more on memorization and test preparation and less on deeper, experiential learning. Our research results suggested that all of these underlying priorities competed with the ultimate goals of the project and resolution required consistent communication and negotiation between project partner groups.

Addressing Partnership Challenges: Scale Support Activities

As challenges emerged we began to implement support activities to strengthen the partnerships and build the capacity of project partners to implement, scale, and sustain the project innovations. These activities included: scale workshops; monthly leadership meetings; formative research memos; and network mapping work sessions.

Annual scale workshops. We began hosting yearly scale workshops led by Chris Dede to build the capacity of project partners to understand the goals and processes of scale research in education. By building capacity of the project team we began supporting the project team's ability to work toward scaling. Our first scale workshop, held in April 2014, focused on defining "scaling up" and identifying its challenges. Partners were introduced to the aforementioned scale framework (Clarke & Dede, 2009). The project partners worked together to articulate their goals for scaling up the innovations of the project and implications were discussed. The second scale workshop was held in March 2015 and focused on "robust curricular design for scale." To address the project partners' difficulties collectively defining the core components of "citizen science," we had participants examine existing, successful citizen science projects. The members of the project partner teams then considered what citizen science curriculum modules for middle grades would look like. Using curriculum modules developed by the first cohort of Students Discover Fellows, participants engaged in a hands-on activity to ruggedize the designs of the lessons so they would function better in varying contexts. At the end of the workshop both implications for Students Discover and the most immediate next steps were considered. Evaluation results indicate that throughout each scale workshop project partners gained a better understanding of each other's roles and challenges and the partners began to develop a shared language for discussing the components of the project.

Monthly leadership meetings. Our observation and interview data showed that the initiation of monthly meetings of the Students Discover leadership helped to clarify partner roles and to improve communication flow among project partners. The format of the leadership meetings has been flexible. Each member describes their team's current project activities and raises any concerns for feedback. These meetings have helped to surface the different goals of

the partner organizations. Furthermore, the smaller meetings provided a "safe" opportunity to discuss issues and identify solutions. Developing relationships and building a sense of trust among the leadership team seems to be a critical component for success.

Formative research memos. As we gathered and analyzed data during the first years of the project, we used formative research memos to present the data and recommendations to the specific project partners involved. The memos were presented and discussed in the smaller leadership meetings, promoting open discussion and building collective understanding. We believe that this process has been important for building the model that is at the heart of Innovation 1.

Network Mapping Work Sessions. As a result of the challenges that emerged in the first two years of the project, the scale team has recently undertaken a network analysis to better understand how the structure of relationships between partners may be facilitating or inhibiting outcomes for the partnerships as a whole. Social network theory suggests that network structure has the potential to impact learning, and it has been increasingly used as a lens to study educational outcomes (Daly, 2010). We have scheduled our first network mapping work session with all project partners for November of this year, facilitated by social network theorist Alan Daly. To complement the network analysis the team has also gathered qualitative data through individual interviews with project partners. Through this we are seeking to understand how individual project members think about central aspects of the projects – such as *what* the innovation is and what scaling looks like – so that we can look for similarities and differences across the project team.

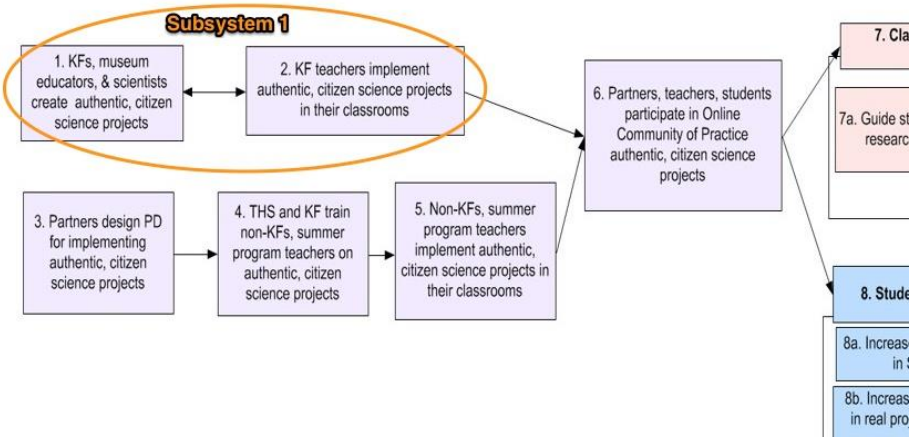
Partnership Subsystems

The length and complexity of this project necessitates multiple, overlapping phases of research and attention to multiple subsystems of partners. Here we report on our research to date of two partner subsystems: (1) teachers and scientists at the museum working together to co-develop and implement citizen science curriculum modules, and (2) teachers and a professional development provider working together to develop and deliver professional develop on the curriculum modules to teachers who were not involved in the project. This phase of research aligns with the "development" dimension of the scale framework. In this phase we are concerned with Innovation 1: the collaborative *processes* by which teachers and scientists, supported by other project partners, co-develop, implement, and refine citizen science curricula and a framework for engaging students in real science.

Subsystem 1: Teachers and Scientists, with Support from Other Project Partners

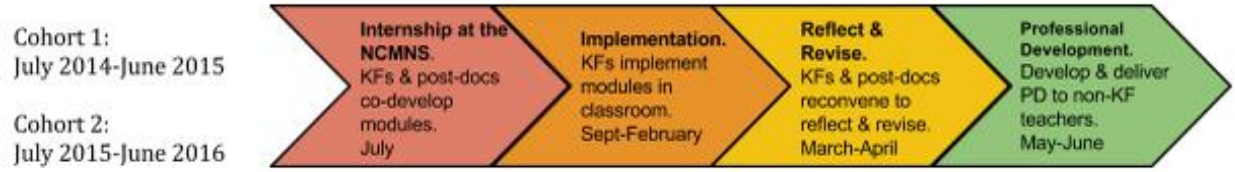
As part of the Students Discover project, 12 Kenan Fellows teachers collaborate with NCMNS scientists to co-develop citizen science curriculum modules for middle school classrooms. The curriculum module development phase begins during this summer internship and extends through the spring of the following school year, allowing the teachers to pilot the modules in their classrooms and make subsequent revisions.

Figure 3. Subsystem 1: Teachers and Scientists



During the first two years of the project we have worked to understand factors that support or constrain the co-development of the modules, studying Cohort 1 and Cohort 2. In doing so we hope to inform and improve the module co-development process for Students Discover Cohort 3 Fellows and, more broadly, to facilitate the development of a scalable model for bringing together scientists, teachers, and others to co-create curricula that engage students in conducting authentic scientific research. Figure 4 illustrates the major activities and timeframe for each cohort of Kenan Fellows.

Figure 4: Activities and timeframe for Cohort 1 and Cohort 2 Kenan Fellows



Subsystem 1: Findings

The findings presented here are based on observations of Cohort 1 and Cohort 2 Kenan Fellows internships at the museum and focus groups conducted with both cohorts of Fellows

during the third week of their internship. The findings also include classroom observations and interviews with Cohort 1 Kenan Fellows and the postdoctoral scientists conducted during the 2014-15 school year.

Support factors. In examining the process of bringing teachers and scientists together to co-develop and pilot citizen science modules, several important support factors emerged: opportunities for teachers to engage in authentic science and experience citizen science from a student's perspective; multiple and varied opportunities for reflection; the approachability of scientists during the internship and the accessibility of them during the implementation phase; identification or development of low-cost alternatives for supplies and equipment; use of digital tools to share resources and work collaboratively; and mutual respect between teachers and scientists for their expertise in their respective professional practice.

Challenges. Despite the many support factors that aided in the development and piloting of the citizen science modules, several challenges emerged during the co-development and implementation of the modules. The greatest challenge, and the one with the most far reaching implications, was the lack of existing citizen science projects from which curriculum modules could be developed. While one lab team worked to build curricula based on "eMammal," an existing citizen science collaboration between NCSU and the Smithsonian Institution, the other labs teams were developing original citizen science activities for their classroom based on the latest research of their lead scientist. They were creating an original product that could *potentially become* a citizen science project accessible to others, but was unproven and had much development and piloting to be done. The scientists leading these labs had data collection systems in place that were sufficient for collaborating with three classes of students, for example, but there were no outward facing data submission mechanisms to be used by larger audiences.

Without a data submission system in place or a publically accessible data repository, the curriculum content developed by the teachers was not able to be used by other teachers for analysis and hypothesizing.

The temporary nature of the postdoctoral scientist position was also a challenge for the Students Discover project in its early stages. During the first two years of the project two postdoctoral scientists left the project to take permanent research positions, and when these scientists left the research ended. Teachers who worked on curricula for these projects were left with good hands-on science activities, but not with citizen science activities. Furthermore, at the end of the first summer internship one post-doc indicated that they had "all the data they needed." This pronouncement left the teachers and other project partners questioning the lifespan and scalability of that particular project as well as the other projects.

In addition to these logistical challenges, several other notable tensions emerged during the internships for Cohort 1 and 2 Kenan Fellows. Misalignment between the content of the scientists' research and the standards to which the teachers were required to teach challenged the module co-development process. This difficulty was exacerbated when the Kenan Fellows taught subjects other than science, for example mathematics, language arts, social studies, or art. Additional challenges included the scientists' lack of familiarity with middle school curricula and standards and the absence of a generalizable approach for engaging students in citizen science.

Beyond co-development of the modules at the NCMNS, challenges also occurred when the teachers began implementing the modules in the classrooms. A few teachers reported a lack of administrative support in their schools, either that their administrators were not aware of their fellowship work or they were not supportive. Also during the implementation year the scientists

reported frustration over the lack of communication from teachers. The scientists noted that it was difficult to know how to best support the teachers when the educators were inconsistently responsive to their communication attempts.

Subsystem 1: Next Steps

To address these challenges we plan to facilitate a series of meetings with partner leads from the NCMNS, the KFP, the scientists, and some of the Fellows to review the social network analysis results. Through these meetings we will identify what the Students Discover partners collectively believe to be the critical components of the teacher-scientist collaborative model. Then, during Cohort 3 Kenan Fellows' internship at the NCMNS in July 2016, we will test again and further refine this model.

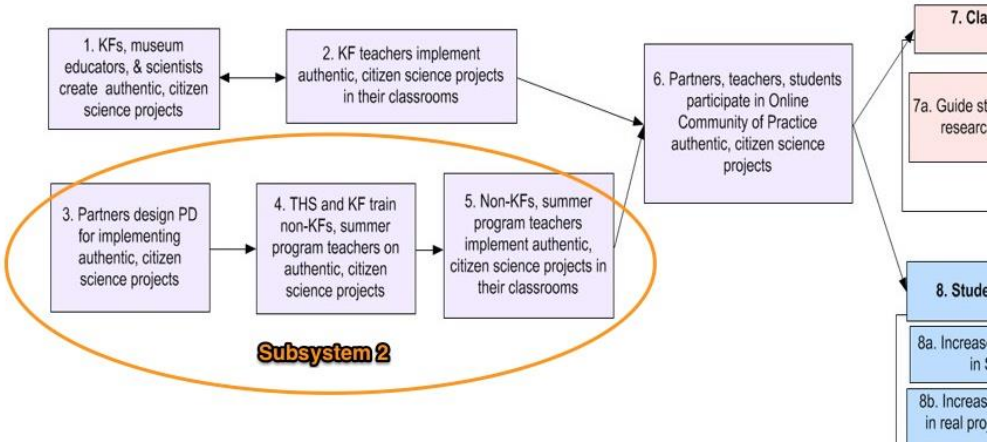
We will also intend to focus on Innovation 2 – *the citizen science curricula and framework for engaging students in authentic science*. Through analysis of classroom observation data and interview data with Cohorts 1 and 2, we will identify sources of effectiveness and critical contextual features of the citizen science curriculum modules. Using a "depth" lens from the scale research framework, we will begin identifying variables that represent important conditions for success. These findings can enable prospective adopters of the citizen science modules to better determine the level of effectiveness they are likely to achieve in implementing the innovation (Clarke & Dede, 2009).

Subsystem 2: Professional Development Providers and Teachers, Supported by Other Project Partners

TSH specializes in developing and delivering high quality STEM professional development to K-12 teachers. During each school year in the Students Discover grant the TSH director and three satellite directors work with the Kenan Fellows to create a three-day

professional development workshop to be delivered to roughly 40 teachers the following summer. The purpose of the workshops is to introduce teachers to citizen science and to provide training on how to implement the Students Discover modules. The point at which the citizen science modules transfer from the Kenan Fellows, who created the lessons and implemented them under greenhouse conditions, to unfamiliar teachers, who may be implementing the modules in less hospitable contexts, is a critical juncture. This process is crucial for the successful progression of scaling. Our research of this subsystem will seek to understand the factors that support or constrain the development and delivery of successful professional development. As part of this research we will also explore the ways these new teachers modify the modules so that the activities function well in their schools and classroom contexts. In this way we our research activities begin investigating Innovation 2 – *the citizen science curricula and framework for engaging students in authentic science*.

Figure 5. Subsystem 1: Professional development providers and teachers



Subsystem 2: Findings

The preliminary findings presented here are based on observations of TSH and teachers working together during 2014-15 to co-develop and deliver the training to 40 teachers at the

2015 summer workshop. We use results from a participant feedback survey collected by the project's external evaluator to supplement our findings.

Planning for the three-day summer workshop began in the fall of 2014. TSH brought together Cohort 1 Kenan Fellows and TSH satellite directors for a two-day planning session on the NCSU campus. During this time, the following general plan was laid out for the workshop:

- Day 1 would be led by the museum educators at the NCMNS in collaboration with Students Discover leadership from the NCSU Biology Department. The purpose of the first day would be to introduce citizen science, give participants an opportunity to tour the labs at the NCMNS, and allow participants to engage in a hands-on citizen science activity at a local eco-station.
- During Day 2, participants would break into four groups, with each group assigned to one of the four NCMNS labs that lead the Students Discover citizen science projects. Using the modules developed by Cohort 1 Kenan Fellows, participants would experience the actual lab research while receiving training on the use of the modules in the classroom.
- On Day 3, each team would present a summary of their experience and the module they worked with to the larger group of teacher participants.

In October 2014 the Cohort 1 Kenan Fellows worked in their lab groups to begin planning the details for the professional development session. For many of the Fellows the timing of this two-day planning session felt premature, since they had not yet piloted the modules in their own classrooms. At the conclusion of the planning session it was agreed that each lab group would work virtually with one of the TSH satellite directors during the school year to continue planning for the coming summer. The planning resumed again in April 2015 and the teams worked

autonomously over email to plan the rest of the professional development. There was little communication or coordination between teams, and there was little communication or coordination between TSH and the NCMNS educators regarding how the workshop would run overall. Along with these challenges, that spring one of the postdoctoral scientists announced they would be leaving to take a permanent position at another institution and another indicated that they had all the data they needed for their research. TSH struggled with how best to develop professional development for citizen science projects that were ostensibly ending. From their perspective, TSH believed they now had to provide teachers attending the summer workshop with good hands-on science activities, but they would not be providing citizen science.

The communication and coordination challenges that occurred during the planning stage resulted in the delivery of a workshop that was less than what TSH and the NCMNS educators hoped it could be. While the 40 participants who attended the summer workshop indicated enjoying the opportunity to network with other teachers and learn about resources available from the NCMNS, few left the workshop feeling prepared to implement the citizen science curriculum modules in the classrooms. Observation data and survey data collected at the end of the workshop revealed several areas for improvement. Teachers wanted a better introduction to citizen science in general. Many did not see the connection between citizen science and what they experienced during the second day of the workshop. Teachers wanted a better understanding of the goals of each project and the intended use of the data that was to be collected. Additionally, teachers wanted more time to engage in hands-on activities. Without engaging in the actual science themselves, teachers did not feel prepared to engage their students in this science. The project partner leadership reviewed this feedback, debriefed about the planning and delivery process, and came to consensus that the model would need an overhaul.

Subsystem 2: Next Steps

Regardless of the challenges faced, with the initial spread of the citizen science modules under way in the summer of 2015, the Students Discover leadership recognized that the school district partners needed to be brought into the project. With guidance and support from our project advisors and leading experts in DBIR (http://learndbir.org/), in late summer 2015 we proposed to the other project partners a new vision and strategy for collaborating with the partner school districts going forward. We suggested making a fundamental shift in how the Students Discover partners structure, and how we study, the work of spreading the modules to teachers across the state – instead of independently building professional development workshops, the Students Discover team would co-design the professional development with the school districts. The leadership at TSH, KFP, NCMNS, the scientists, and others were in rapid agreement and were immediately excited about that approach.

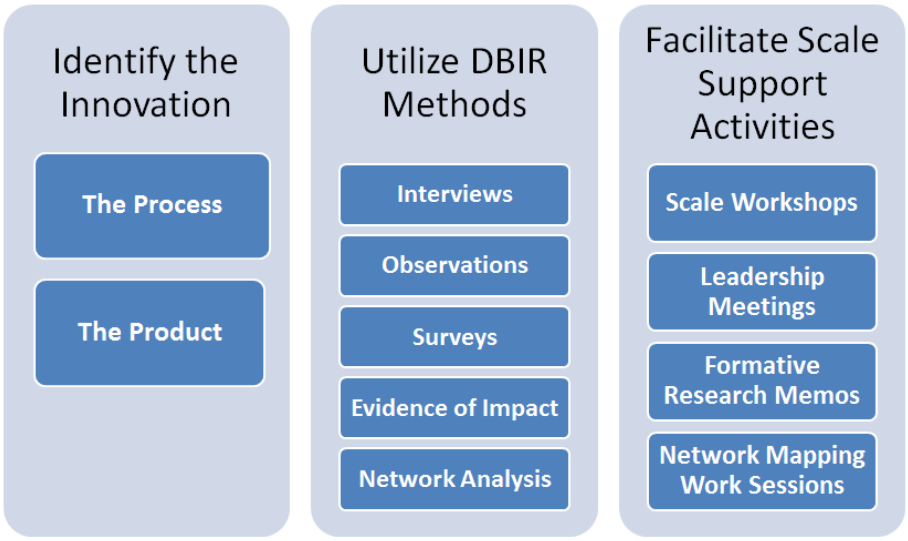
Moving forward, into fall of 2015 and throughout the remaining three years of the project, the Students Discover team will prioritize collaboration with the district partners and we will apply DBIR methods to study this process. DBIR is a new generation of design research in which the focus is not only on the specific educational innovation, but also on the institutions and communities of practice that ultimately enable or constrain the sustainability of that innovation (e.g., Fishman, Penuel, Allen, et al., 2012; Penuel & Spillane, 2014). As revealed through the results of our network analysis and observations, the partner school districts were operating on the periphery of the project until summer 2015. They were brought in for occasional meetings to be updated on the work being done by those who were more central to the early work. In the coming year TSH, the scientists, and the NCMNS educators, with support from the scale research team, will work closely with the partner school districts to understand their needs,

priorities, resources, and existing support structures. Together these project partners and the school district staff will develop models for the citizen science professional development that best meets each district's needs. They will also build ongoing support structures, within the districts' infrastructure and operations, which will better enable the citizen science curriculum modules to take root and thrive within the districts.

DISCUSSION

One of the greatest challenges of educational improvement is the difficulty of scaling up locally successful innovations to a wide variety of settings while maintaining the effectiveness, affordability, and sustainability of the innovation (Dede, 2005). The purpose of this scale research is to examine a process for moving the Students Discover citizen science educational innovations from more ideal settings to a variety of school and community-based settings where conditions for success may be less favorable. Thus far we have identified the following critical components for scale research: identify the innovation; use DBIR methods; and facilitate scale support activities (see Figure 6).

Figure 6. Critical Scale Research Components



Our current design for studying the scaling of educational innovations has been achieved by integrating the scale framework developed by Coburn (2003), Dede, Rockman, and Knox (2007) with a DBIR approach as articulated by Fishman, Penuel, Allen, Cheng, and Sabelli (2012). In DBIR the research focuses on not just the development of a new innovation, but also on the development of systems to support its sustained implementation (Fishman et al., 2012). As we have been studying scale, we have been calling the innovation, the "*product,"* and the systems to support implementation, the *"process."* We propose that every innovation is comprised of these two equally important parts. Through the iterative cycles of a DBIR approach (design, action, analysis, and redesign), where the refutation or support of hypotheses in one cycle feeds into new hypotheses for the following cycle, scale researchers can glean important information about how interventions function in specific contexts and how project teams have designed them to do so (Kaplan, Katz, & Flum, 2012). In other words, while a more traditional study would be able to tell us that something is working, the DBIR approach will allow us to

understand why the programs were structured in a certain way and the context-based outcomes of those design decisions. In scale research this information is critical for understanding how programs or interventions will need to be ruggedized to function in new environments. The DBIR approach also allows research findings to be reported back to the project team, so the team can continually improve the intervention for its current context and then ruggedize it for new contexts. Within this overarching DBIR approach we have found that social network analysis (SNA) plays a key role. SNA is illuminating the patterns of interpersonal relationships within the project team – information crucial to understanding the process component of the innovation.

References

Clarke, J., & Dede, C. (2009). Robust designs for scalability. In L. Moller, J. B. Huett & D. M. Harvey (Eds.), *Learning and instructional technologies for the 21st century* (pp. 27-48) Springer US. doi:10.1007/978-0-387-09667-4_3

Coburn, C. E. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. *Educational Researcher, 32*(6), 3-12.

Daly, A. J. (Ed.). (2010). *Social network theory and educational change*. Cambridge, MA: Harvard Education Press.

Dede, C. (2005). Why design-based research is both important and difficult. *Educational Technology, 45*(1), 5-8.

Dede, C. (2006). Evolving innovations beyond ideal settings to challenging contexts of practice. *The Cambridge handbook of the learning sciences* (pp. 551-566)

Dede, C., Rockman, S., & Knox, A. (2007). Lessons learned from studying how innovations can achieve scale. *Threshold, 5*(1), 4-10.

Fishman, B., Penuel, W. Allen, A., Cheng, B., & Sabelli, N. (2013). Design-based implementation research: An emerging model for transforming the relationship of research and practice. *National Society for the Study of Education Yearbook, 112*(2), 136-156.

Fishman, B. J., Penuel, W. R., & Yamaguchi, R. (2006). Fostering innovation implementation: Findings about supporting scale from GLOBE. Paper presented at the *Proceedings of the*

Penuel, W., Riel, M., Krause, A., & Frank, K. (2009). Analyzing teachers' professional interactions in a school as social capital: A social network approach. *Teachers College*

Record, *111*(1). Retrieved March 18, 2015, from http://www.tcrecord.org/Content.asp?ContentID=15174.

7th International Conference on Learning Sciences, pp. 168-174.

Kaplan, A., Katz, I., & Flum, H. (2012). Motivation theory in educational practice: Knowledge claims, challenges, and future directions. *APA educational psychology handbook*, *2*, 165-194.

Means, B., & Penuel, W. R. (2005). Scaling up technology-based educational innovations. In C. Dede, J. Honan & L. C. Peters (Eds.), *Scaling up success: Lessons from technology-based educational improvement* (pp. 176-197). San Francisco: Jossey-Bass.

Moolenaar, N. M. (2012). A social network perspective on teacher collaboration in schools: Theory, methodology, and applications. *American Journal of Education, 119*(1), 7-39.

National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. (2011). National Assessment of Educational Progress [NAEP] Data Explorer. Accessed from http://nces.ed.gov/nationsreportcard/naepdata/.

National Research Council [NRC]. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education, Washington, D.C.

Penuel, W.R., Fishman, B.J., Cheng, B.H., & Sabelli, N. (2011). Organizing research and development at the intersection of learning, implementation, and design. *Educational Research, 40*(7), 331-337.

Penuel, W., Riel, M., Krause, A., & Frank, K. (2009). Analyzing teachers' professional interactions in a school as social capital: A social network approach. *Teachers College*

Record, *111*(1). Retrieved March 18, 2015, from http://www.tcrecord.org/Content.asp?ContentID=15174.

Penuel, W. & Spillane, J. (2014). Learning sciences and policy design and implementation: key concepts and tools for collaboration. In K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences, 2nd Edition* (pp. 649-667). New York, NY: Cambridge University Press.

Penuel, W. R., Sun, M., Frank, K. A., & Gallagher, H. A. (2012). Using Social Network Analysis to Study How Collegial Interactions Can Augment Teacher Learning from External Professional Development. *American Journal of Education*, *119*(1), 103–136.

Sabelli, N., & Dede, C. (2001). *Integrating educational research and practice: Reconceptualizing the goals and process of research to improve educational practice.* Unpublished manuscript. Retrieved October 16, 2012, from http://www.virtual.gmu.edu/integrating.html.

President's Council of Advisors on Science and Technology (PCAST). (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics*. Washington, D.C.: Executive Office of the President.

Trautmann, N. M., Shirk, J. L., & Krasny, M. E. (2012). Who poses the question? Using citizen science to help K-12 teachers meet the mandate for inquiry. In J. L. Dickinson & R. Bonney (eds.), *Citizen science: Public participation in environmental research* (pp. 179-190). Ithaca, NY: Cornell University Press.

Wilson, C. D., Taylor, J. A., Kowalski, S. M., & Carlson, J. (2010). The relative effects and equity of inquiry-based and commonplace science teaching on students' knowledge, reasoning, and argumentation. *Journal of Research in Science Teaching, 47*, 276-301.

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