Science Teacher Transformation through Collaborative Inquiry: Evidence for the Role of Context, Community, and Identity

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INTRODUCTION

Increasingly, the documents that have served as guideposts for state agencies and policymakers as well as individual school districts for K-12 science learning have emphasized not only knowledge of scientific content, but also of the process by which scientists address questions about the way the world works (e.g., American Association for the Advancement of Science, 1993; National Research Council, 1996). For students to achieve this level of understanding, the teaching of science must undergo a radical shift. For teachers to alter their practice so that it addresses these new standards, they must have the opportunity to come to understand science differently themselves (e.g., van Driel, Verloop, & de Vos, 1998). Unfortunately, most professional development opportunities are short-term, take little account of the specific context in which teachers work, and address only a very narrow set of issues in the very complex array that comes together in classroom environments to determine the extent to which learning will take place. Our work has been focused on the design and implementation of two large-scale professional development projects in two different areas of the U.S. that have been focused on the reform of elementary and secondary science teaching. One of these projects, which has just completed its second year, has at its heart the use of model-based reasoning as a foundation for successful science teaching and learning (e.g., Passmore, 2008; Windschitl, Thompson, & Braaten, 2008); the other project, which has just completed its sixth year, has been centered on the principles guiding the development and maintenance of effective communities of practice (e.g., Borko, 2004; Lee, Songer, & Lee, 2006; Newmann, King, & Youngs, 2000; Jin & Richmond, 2008; Richmond & Birmingham, 2009) and models of distributed leadership, particularly in urban contexts (Spillane, Diamond, Walker, Halverson, & Jita, 2001). While the contexts and frameworks upon which these projects are based differ somewhat, the success of both projects is the result of some common factors which contribute to the ability of project participants to engage in collaborative inquiry in contexts designed specifically to support such work. That is, a central feature of both projects is the development and maintenance of professional learning communities engaged in collaborative teacher inquiry around particular approaches to science teaching. Our intent in this paper is to present a series of claims about the contributions made by these two projects with respect to understanding the landscape of teacher change and the conditions that can support the transformation of practice and to use evidence from our work to support these claims. Our ultimate goal is to propose ways in which such work might contribute to the development of a set of design principles to guide the research community and educators in their efforts to understand and better implement professional development activities to support teacher learning and the transformation of practice.

DESCRIPTION OF PROJECTS

The PICRUST (Professional Inquiry Communities for the Reform of Urban Science Teaching) Project has been situated in a Title I urban district of more than 17,500 students, with 58% minority students and 63% of its students on free and reduced lunch. The intent of this project is to create the infrastructure and a set of human, material, and social resources that will develop K-8 science teacher leaders, support and retain new teachers, and sustain professional

growth throughout teachers' careers. The framework for the project arose out of social cognition/sociocultural theory and research on affordances for teacher change provided by professional learning communities (PLCs). Each year a different curriculum unit or topic was chosen as the *focus unit*. For 1-2 weeks during the summer, grade-specific Summer Learning Institutes were held during which teachers worked on sharpening their knowledge of scientific content and inquiry. Following the SLI, each grade-specific PLC (which ranged in size from 3-10) met bi-weekly during the school year where work continued on the focus unit, with particular emphasis on curriculum materials design and revision, and participants made use of the research literature on student ideas/misconceptions, national standards documents and associated resources, and assessments and analysis of student work in the development and revision process. Units that were developed featured ongoing involvement of students in scientific inquiry—the identification of explanations for patterns observed in data, and application, which involved the fitting of models and theories to new data (Anderson, 2007). Each group was facilitated by a senior staff member and a graduate assistant, who documented the activities of the SLIs and PLCs. The facilitator observed lessons from the focus unit being taught by each member of the group, before and after which the teacher and facilitator met to talk about objectives, challenges, successes, and revisions; this information was then brought back to the PLCs for discussion with the entire group, and revisions were made as appropriate and agreed upon. A separate PLC was established in Year 3 for building administrators so that they could become familiar with the criteria and practices associated with reform-based science teaching and could learn to develop capacities to support staff at their building. Teachers with multiple years of experience in the project served as mentors for both new teacher participants and to university teacher candidates for their field placements in the last two years of their certification program, and these candidates became regular project participants. Over a period of six years, more than 60 teachers and administrators have participated in the project.

The focus of the professional development work Inquiry in to Practice grant is model-based inquiry. Briefly, the goal of model-based inquiry (MBI) is to replicate in the classroom important aspects of science as it is actually practiced. Students are engaged with data and data patterns derived from natural phenomena and learn about or develop conceptual models that can account for those phenomena. Like "real" scientists, the intellectual work of students in an MBI classroom is about exploring and explaining the natural world and in the process they develop a deep understanding of both the scientific enterprise itself and the concepts of a particular discipline.

Because few teachers are familiar with a view of science and science education that is explicitly focused on modeling and model-based reasoning, ISIM includes an intensive professional development sequence called **Innovations in Science in Instruction through Modeling (ISIM)**. Beginning in the Spring of 2007 a cohort of 24 teachers began the 2-year sequence in which they first learned about models in science and developed a perspective on science learning based on the MBR framework. They were then asked to translate that learning into their own teaching practice in collaborative teacher inquiry teams in which they work with colleagues on curriculum development in a modified lesson study cycle. During the academic year each team of teachers, supported by project staff, developed and implemented a series of lessons based

on the MBR framework and then critically examined the curriculum enactment by examining student work and, when possible, observing one another teach. They reported on their curriculum development and implementation at a symposium in the Spring of 2008 and then participated in a second intensive summer institute followed by a second lesson study cycle.

The first cohort of ISIM consists of 7 teams of teachers from 6-12th grade. There are 3 middle school teams representing each grade level and 4 high school teams, one each in Earth Science, Physics, Chemistry, and Biology.

CLAIMS ABOUT PROFESSIONAL DEVELOPMENT AND EMPIRICAL EVIDENCE FROM THE PROJECTS

In the section that follows we present a set of three major claims about the important features of our professional development projects and their role in the transformation of practice. We begin with the basic premise that traditional professional development is insufficient for transformative change. The projects described here do not test that assumption; rather they explore the affordances of a different kind of professional development, one that is sustained over a long period of time (years), is carefully scaffolded, is not about 'training' focused on a specific curriculum or skill, but rather provides opportunities for professional experimentation, and is designed around a two-way transmission model (i.e., it respects and in fact takes advantage of the diverse set of experiences and expertise teacher participants bring with them to the professional development setting). In other words, both of these projects engage teachers in sense-making about the reform put forth by engaging them in collaborative teacher inquiry. In this kind of professional development model, our research shows that three elements are key in the change process: community, context, and identity. We want to acknowledge that these three claims are in reality quite interconnected and interdependent and, as a whole, define what we recognize as critical features of effective professional learning communities. We treat them as separate claims and design principles here in order to be explicit about the contributions of each.

Both of the projects represented here are funded as research into professional development by the National Science Foundation. As such, they go beyond mere implementation of a professional development program to documenting teacher change and the process teachers undergo during the programs. The corpus of data from each project is large and each project has undertaken a number of independent analyses (i.e. Jin & Richmond, 2008; Passmore, 2008) The results of these will be presented in more detail during the symposium, but our primary purpose here is to look across findings from both of the projects to identify more generalizable claims. Data sources in support of these claims include recorded teacher talk during meetings and study groups, videotapes and field notes of participant teaching, written artifacts from teachers such as curriculum revision notes, unit templates, participant interviews, pre- and post-institute assessments and responses to reflective writing prompts.

Claim One: Community

Overview. Communities provide support and intellectual space for professionals to explore new ideas, come to understand those ideas, and imagine how those ideas may be implemented (e.g., Grossman, Wineberg, & Woolworth, 2001; Little, 2002a, 2002b).

Related representative empirical findings from PICRUST and ISIM.

- PICRUST participants interviewed during the final two years of the project reported that they were more likely to share their practice—both the successes and the challenges--with other teachers participating in the project than with colleagues in their own building who were not participants.

- In both projects, it was observed that, over time, an increasing amount of "teacher talk" has been focused on curriculum-based problem-solving. In one of the PLCs in PICRUST, for example, the amount of talk focused on such issues as complaints about administrative support, lack of resources, job uncertainty, declined from more than 60% of session time to less than 20% over time, while talk centered on curriculum development, analysis of student work, and resources to support instructional strategies showed a corresponding increase.

- Participants identified sensitivity to needs of participants and of co-construction of priorities, tasks and products as important to developing trust and common purpose.

- As planned project participation comes to an end, the participants have been very vocal about how to maintain their collaborations and their work. More than 80% of participants who began their participation in PICRUST at its inception continued to participate in the project's final year. Half of the remaining 20% who did not continue to participate had either been moved to another school or had left the district. At the end of the second summer in ISIM, participants were surveyed about their interest in continuing the work and 100% of the teachers professed a desire to maintain participation in the community even after the formal program had ended.

- Teachers have become much more forthcoming about constraints and the teacher talk has centered on how to incorporate reform practices despite these constraints (group problem solving).

- Acknowledgment on the part of participants that they are able to achieve more in collaboration with their colleagues than they would have been able to do alone. Specifically, they discussed that when they found themselves stuck, a colleague was usually able to help them work through the problem.

- Teachers stated that it was having a group to report back to that kept them going at times. The group provided a measure of accountability and expectation that pushed them to enact new practices.

- Some teachers report that the sense of professionalism associated with their participation in the community has kept them in teaching. For example, at the end of the second summer institute, sample teacher comments from ISIM included:

    - *"The greatest gift I have been given however has been a sense of hope and vision for teaching as a lifestyle not just a career. Along with that I have felt valued as a person and as a professional"* (AS, BBS-2, 7/24/08)
    - *"I am very grateful for this collaborative community of teaching professionals - it keeps me going when things don't quite work this way at school."* (EG, BBS-2, 7/24/08)
    - *"The community of professionals that was created in ISIM made all of my growth and learning possible."* (MH, BBS-2, 7/24/08)

- As the project progressed teachers placed high confidence in the expertise of their peers instead of always looking to leadership team for answers. For example, in the second year of the professional development program for ISIM, the teachers teams each made a contribution to the summer institute that varied in length from 2-4 hours. The areas covered in these sessions included identifying critical models across the curriculum, lesson sequencing and flow, how to scaffold student written argumentation in model-based classrooms, and assessment. In end-of-institute evaluations, many teachers felt that hearing from their peers about how they had addressed some of these important issues was one of the most valuable features of the summer institute. Sample evaluation comments included:

    - "*…the conversations and revelations by the other groups were totally enlightening and reassuring because some of the same issues and struggles were similar. It was nice to know we weren't alone in our work with models*." (AR, BBS-2, 7/24/08)
    - "*Group contributions such as the explanation protocol. Seeing and hearing from folks on topics I too have grappled with. And getting suggestions and ideas from others in a productive non threatening atmosphere.*" (AB, BBS-2, 7/24/08)
    - "*Also talking with the others and learning from their experience, seeing so many common problems, so many similarities in our journeys helped*." (GM, BBS-2, 7/24/08)
    - "*The presentations by each group were fabulous. We all had to deal with similar questions and problems and it was so useful to have each group really explore one of those in depth. Many great ideas and thoughts came out of those sessions.*" (HL, BBS-2, 7/24/08)
    - One teacher shared the following at the end of the PICRUST, *"One of the greatest things about the project was the different expertise each of us brought. Amy was really good at posing questions that told her a lot about her students' understanding, Jack knew a lot about the science content, and Justin had a way with his kids*. *I just learned a LOT about science teaching!"*

Across both projects, we have identified the critical role that creating space, building trust, and co-constructing knowledge play in establishing and maintaining effective professional communities. The communities then become the center of the professional development work. It is in the context of working with their peers and with colleagues from the University-based projects that the teachers were able to explore, make sense of, and begin to envision enactment. The community also played an important role in keeping participants involved in the project over time and helped them take risks and accomplish more than they might have if working in isolation.

Claim Two: Context

Context is key to grounding the work and providing opportunities for salient features of instructional practice to arise naturally. Here we mean context in two senses: first that professional development (PD) that is sensitive to the instructional/school context of the teacher is critical for the teacher to see the relevance of the work (Garet, Porter, Desimone, Birman, & Yoon, 2001), and second, that some kind of framework or reform teaching practice provides context for conversations about many aspects of practice like assessment, lesson sequencing, task design, and the like. (Stewart, Cartier, & Passmore, 2005; Richmond & Schwarz, 2005).

Related representative empirical findings from PICRUST and ISIM

- Participants repeatedly expressed appreciation for the project being focused on content they were expected to teach rather than isolated or general professional strategies. As one teacher said, "*I chose (to participate in) (PICRUST) because of its in-depth aspects, and what (it focuses on) in the classroom, and also it was for our district...".*

- Teachers initially found the framework developed for planning and curriculum assessment/revision/development difficult and complex but with some negotiated revisions and support these served as critical anchors for planning, teaching, assessment, and revision. In particular, in ISIM, the teachers struggled with the meaning of the word model and how models operate in science. Their attempts to make sense of this, however, provided opportunities for them to discuss a range of issues related to school science such as how the model-based inquiry framework interacted with their views on the goals and purposes of science education, how it was consistent or not with their views of learning, and how it pushed them to reflect on the organization of their curriculum (Passmore, Xiang, Hedman, & Hvidsten, 2009). During the spring symposium at the end of year one, a common theme across the presentations was that the teachers expressed surprise at the extent to which curriculum developed using a modeling perspective touched on a wider range of standards than they had initially thought it would. That is, the teams saw that placing fundamental models at the center of their curriculum had important payoff with regard to coverage, an issue they all felt pressure around.

- Each of the PLCs had a unique character and while their overall goals were identical, they proceeded at different paces and foregrounded different issues which reflected the needs and expertise of the group's members. For example, in ISIM, in the second year lesson study teams a variety of things happened. Some teams continued to revise and expand on the lessons developed in the first year, other teams chose to tackle a new curricular area for the second year, and some chose to focus on more general strategies for getting students to engage in model-based inquiry.

- The natural emergence of issues related to teaching such as assessment, lesson sequencing, and instructional decision-making provided opportunities for teachers to explore the aspects of the reform that were most salient to them at the time (Passmore, Xiang, Hedman, & Hvidsten, 2009).

Across both projects, we have observed that responsiveness to context resulted in two critical outcomes: first, the development of more receptivity amongst participants to the project tasks and goals, and second, the design of structures and resources that take into account the experiences and needs of both practitioners and their students. The professional development projects were flexible and allowed for issues of context to rise to the surface and become a driving force in teacher learning.

Claim Three: Identity

The professional development frameworks and the opportunities they offer for transformative practice interact with the identities teacher participants bring with them into the projects (see, for example, Sfard & Prusak, 2005) and determine in part the extent to which they take up and implement the reform.

Related representative empirical findings from PICRUST and ISIM

- Videotapes and observations of teaching revealed teachers taking instructional risks which they reported they would never have taken without support of the group.

- Many teachers who initially expressed some lack of confidence in their science teaching skills offered to become mentors for other teachers in the group, at their school, and for teacher candidates." *I was weak when coming into science...and PICRUST has helped me be a better science teacher...I give building peers support; they come to me for materials...we advise on experiences, we talk about how kids are confused on certain issues and how we can change this...".*This teacher is now collaborating with several of our science education faculty and with elementary teacher candidates in the university classroom and in the field.

- Several teachers have been asked to lead workshops in their school and district and on district curriculum steering and assessment writing committees and thus are taking on different roles in their buildings and districts. Teachers in ISIM have become more

actively involved in training of new teachers and readily volunteer to participate in science education research projects conducted by University collaborators.

- Several teachers are serving as facilitators for multi-district curriculum development project to respond to new state grade-specific K-7 science benchmarks. One such teacher expressed the following: "*Before PICRUST, I was just using the science kits given to us and assumed that they were good and followed lesson after lesson....I (learned) curriculum analysis and looking at benchmarks, (how to) help our students construct knowledge instead of telling them information, looking at the developmental appropriateness of content and assessment, looking at misconceptions and what students may need. And (my own) background knowledge on content."*

- Teachers exhibited evidence that they thought of themselves as emerging experts when they worked with their groups to offer sessions during the summer institute.

- Several teachers have undertaken much more significant curricular reform than required from the project and seem to view their role as teachers to be very different from the role they had at the beginning of the project. In a recent survey of teachers from ISIM, all indicated that they were likely to expand the reform into areas of their curriculum that had not been a direct focus of the professional development project with 77% of teachers placing their likelihood of expansion between 8-10 on a ten point scale (Passmore, Hvidsten, & Xiang, 2009).

Across both projects, we have identified how significant professional identity is in determining the extent of uptake of project goals and willingness to take risks with respect to practice. We also have observed that there are elements of PD project design that can serve as catalysts in setting the stage for shifts in this identity. Asking teachers to work with colleagues to enact new curriculum and instruction allows them to experiment with new roles and identities. These shifts are accompanied by changes in the teachers' sense of agency, which in turn influences the sustainability of changes in practice.

FROM CLAIMS TO DESIGN PRINCIPLES

As we examined the empirical findings from our projects and the claims that arose from them we began to consider the implications of these findings more generally. The evidence we have for the importance of community, context, and identity in supporting transformation of teaching practice leads us to propose a set of design principles that can anchor future work and serve as a practical guide to others engaged in similar efforts.

Design Principle #1: Create Community

Our findings point to the critical role that community plays in supporting and sustaining teachers in changing their practice. Teachers are often very isolated in their work and, as Grossman et al (2001) have pointed out, teachers involved in reform-based practice may find

themselves changed but also find themselves practicing in an unchanged workplace. This makes it all the more important for those who are attempting to alter their practice and experiment with new instructional approaches to have a group of peers and colleagues with whom they can discuss issues as they come up. Simply placing participants together in a group is not sufficient to create a sense of community, however. The community should be made up of participants with diverse expertise and the activities designed to ensure that each member of the group can contribute. In addition, a critical feature of effective communities is the co-construction and regular re-norming of the group's goals and priorities. It is the way in which the work of the group is organized and the ways in which common goals are articulated and negotiated that allow a diverse group of people to become a supportive, collaborative, and intellectually stimulating community. (See also, for example, Stein, Smith, & Silver, 1999; LaChange and Confrey, 2003.)

Design Principle #2: Build Content that is Sensitive to Context

Our findings indicate that creating an opportunity for teachers to explore reform practices in such a way that they can see the relevance for their teaching context is important for gaining buy-in and sustaining involvement over time. Altering teaching practice is difficult to achieve, and if a teacher does not see the connections of a particular approach to his or her practice then implementation may be either nonexistent or superficial and fleeting. Professional development, like good science teaching, should engage teachers in constructing their understanding of the reform being put forward as they apply it to the particulars of their teaching context. Key to this is the ability of organizers to provide rich problem spaces for participants rather than presenting approaches and instructional innovations in a canned format using a one-way transmission model. In our projects, this has grown out of our emphasis on inquiry and model-based reasoning. Participants struggle with the new ideas being presented as they work to make sense of them and elaborate on them in ways that are relevant and useful for them. While many rich exemplars of reform curricula are used in each project, there is not a view that the teachers are being "trained" to use these materials blindly. Rather, they are asked to view these curricula and the experiences they had learning with them as resources that can aid them as they translate the underlying principles into their own teaching practices.

Design Principle #3: Foster Shifts and Development of Coherence in Professional Identity

Teacher identity plays a critical role in the transformation of practice. Identity and agency are tied to one another in important ways in that without a clear sense of themselves as teachers and professionals, teachers may feel they lack the skills and power to enact change. Thus, any professional development aimed at significant transformation will need to attend to the evolving and shifting identities of the participants. In practical terms this means that the project needs to be long term enough to allow for such shifts, but more importantly it needs to provide opportunities for teachers to take on varied roles with attendant support. In our projects, participants were encouraged to experiment with the reform approaches being put forth and to make their efforts public in a scaffolded way. In this way the changing roles of the teacher could

become the focus of reflection, discussion and change in a recursive manner.

FINAL THOUGHTS

What conclusions does our work, with its claims and design principles, lead us to when it comes to addressing issues of collaborative teacher inquiry? We propose that there are three primary issues. These include 1) the challenges associated with sustaining and scaling up such efforts, 2) the criteria for fidelity of replication by professional development specialists, and 3) the evidence needed to convince stakeholders, such as policymakers and administrators and contribute to the research community.

We are certainly not the first to call for professional development which is sustained and purposeful, involving deep collaboration between and among participants and leaders. However anyone who makes such calls is confronted with the issue of sustainability and scale up. Our claims and design principles are based on intensive studies on relatively small programs that were well-funded through extramural grants. These efforts involved close involvement and partnership between university science educators and scientists and school based teachers and administrators. It is a tension that some of the elements that led to the success of these projects are precisely the elements that are difficult to sustain and/or build up. Our challenge then is to think in creative ways about how to make the collaborative inquiry at the core of these projects accessible and relevant in bringing projects to scale.

We have identified three design principles that we derive from our work, but what those actually look like in practice is left somewhat underspecified here. However, moving forward, our community will need to develop a set of criteria for how these elements (and others deemed essential) might be evaluated so that claims across projects around design elements might be compared. Moreover, a set of guidelines for what counts as collaborative inquiry would be useful as this intention is instantiated in a wide range of PD designs.

And finally, our community must take up the issue of how to convince those in decision-making positions that the types of professional development opportunities we are discussing here, ones that respect and capitalize on the expertise of *all* participants, are vital to the reform of teaching practice in science. In order to do this, it will require better and more thorough documentation of both teacher learning and student achievement. And, more importantly, the connection between the two. The *gold standard* by which success is measured is the extent to which specific gains in teacher learning are associated with specific gains in student achievement; the latter in particular must be observable using instruments which are not only reliable and valid, but meaningful to those outside audiences who have the power to support and enhance the kind of culture which makes such gains possible. What we have shared here represent beginning steps in constructing a compelling argument about the power of such communities of inquiry to achieve such ends.

That is, the most convincing cases will come from evidence-based arguments that couple the particulars of teacher learning/transformation with specific gains in student achievement.

Additionally, teachers themselves must be convinced that participation in such intensive efforts is worth their time and so evidence about feasibility and desirability of reforms must be gathered as well.

To summarize, in this paper we undertook analyses of two professional development programs that were based around collaborative inquiry to understand and highlight what we viewed as the central features of those programs. We found three areas that we believe were crucial to the success of our programs, but that can also inform others undertaking similar work. From these we proposed a set of design principles that may serve as guides to the construction of professional development experiences for science teachers. As we end, however, we'd like to acknowledge that this work is still in its infancy and beyond the specific claims we've made here, we want to use this paper to begin conversations with others engaged in similar meaning-making from their collaborations with teachers. Like teaching itself, much professional development is done in isolation without serious attention to looking across projects for ideas that transcend the particulars of specific programs to those that might be generative for the community as a whole. We hope that this can serve as an opening to such discussions.

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