12 Teacher Design Research
An Emerging Paradigm for Teachers’ Professional Development

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Introduction
This chapter presents a new approach to teachers’ professional development called Teacher Design Research (TDR), whose goal is to promote the growth of teachers as adaptive experts. The premise of the TDR approach is that the involvement of teachers in long-term cycles of design research (Kelly, 2003, 2004) may have the potential to promote profound learning of content, encourage their adaptive expertise in the classroom, and prompt them to rethink their beliefs and practices.

TDR challenges teachers to undertake research activities in their classrooms by designing and testing instructional material prototypes (including software) and participating in novel teaching procedures involving other teachers (working in teams with a research team) engaged in multiple cycles of data collection about their students’ learning. The failures or successes of such designed activities to promote students’ learning can prompt teachers to reconsider their core teaching ideas, beliefs, and competencies. Thus, the instructional aspects of TDR come not from outside experts, but, rather, from the teachers’ cognitive dissonance experiences as designers in design cycles.

Teachers’ perspectives and practical knowledge of adapting classroom practices are paramount. As researchers learn about applied teaching approaches and as teachers as designers wrestle collaboratively with their individual and collective interpretations and practices, they naturally explicate and reformulate their understanding of teaching and learning issues. Teacher design research then becomes a context of inquiry that meaningfully provokes teachers to restructure their core ideas, beliefs, and practices. The shared and collaborative nature of TDR can work toward establishing the mutual trust in problem solving and the theory-building that is needed to go beyond local contexts and practices in the social processes and to support diffusion of innovations. The tenets, characteristics, and an illustrative example of TDR supported with qualitative data are described in detail below.

Design Framework
Collinson (1996) characterized teachers’ professional development as typically involving:

- In-service workshops that emphasize private individual activity.
- Brief single sessions that offer often unrelated topics.
- Reliance on an external “expert” presenter.
- An expectation of passive teacher-listeners.
- An emphasis on skill development.
Similarly, Sparks (1995) described teachers’ professional development as an atheoretical activity where quick visible results are expected and where the emphasis is on “training” teachers outside the context of the classroom. Teachers’ professional development activities seem to focus primarily on their expressed needs rather than on explicit linkages to expectations about students’ learning (Sparks & Loucks-Horsley, 1989). Although teachers’ professional development efforts in educational reform are ubiquitous, their value has been questionable (Borko, 2004).

Some theorists argue that the goal of professional development for teachers is to help them grow as “adaptive experts,” which requires “moving beyond existing routines and often requires people to rethink key ideas, practices, and even values in order to change what they are doing” (Hammerness et al., 2005a: 361). Developing adaptive expertise among teachers means that they go beyond their existing routines to reconceptualize their practice in order to address both efficiency and innovation in their teaching (Schwartz et al., 2005).

In this section the six tenets of Teacher Design Research as a design framework are discussed.

**Teacher Design Research Should be Directed Toward an Instructional Challenge that Evidences Significant Conceptual Complexity**

The investment of time and resources required for TDR should not be applied to the teaching of straightforward concepts or simple procedural knowledge. Teacher design research grew out of a National Science Foundation CAREER project to address the problem of teachers’ progression toward two significant challenges: (a) to develop scientific literacy among young children, and by (b) integrating reading comprehension strategies into, scientific thinking (National Research Council, 2000; Snow et al., 2005). Researchers have called for studies of teachers’ views, beliefs, the implementation of inquiry processes, and how these processes may intersect with appropriate reading strategies for scientific subject matter (Keys, 1999; Keys & Bryan, 2001; Palincsar & Magnusson, 2000). Part of the problem lies in the fact that inquiry processes are defined and implemented differently by teachers and researchers in both reading and science (Anderson, 2002; Haury, 1993). A further complication was that suitable instructional materials were difficult to locate, and theories of intervention were underdeveloped.

**Teacher Design Research Should be Applied when Teachers’ Traditional Professional Development Appears Unequal to the Task**

This tenet follows from the first one. The instructional and learning problems should be of a magnitude and complexity not likely to be addressed by brief training sessions for teachers. Instead, TDR draws on the current ideas of theorists about professional development for teachers who recommend:

- Immersing teachers in an intensive experience that focuses on deep learning of the content and processes by challenging them at their level of competence (Loucks-Horsley et al., 1998).
- Having teachers learn by constructing their own meaning from current experiences using previous knowledge (Loucks-Horsley et al., 1998).
- Supporting teachers to understand more fully the processes of learning through active inquiry (Loucks-Horsley et al., 1998).
Promoting learning about practice in practice (Hammerness et al., 2005b).
Focusing teachers on how students learn new content and processes (Loucks-Horsley et al., 1998; Joyce & Showers, 1995).
Building learning in professional communities with shared goals among teachers (Hawley & Valli, 1999) that includes peer coaching (Joyce & Showers, 1995).
Helping teachers develop a sense of self-efficacy in their ability to impact students (Fullan, 1991) through a shared understanding of the purposes, rationale, and processes involved in the innovation (Hawley & Valli, 1999).
Modeling new strategies and helping teachers practice them (Joyce & Showers, 1995).
Moving from deficit-based to competency-based approaches (Smylie & Conyers, 1991).

Teachers’ Professional Development Can be Fostered Through Their Direct Involvement in Multiple Teacher Design Research Cycles

In a TDR experience, teachers participate directly in such activities as:

1. Needs assessment or needs analysis processes.
2. A collaborative review of the literature.
3. A contextual analysis of their school, school district, and state culture and environment.
4. Data collection and analysis of their own and their colleagues’, students’ and experts’ learning.
5. An audience analysis and the construction of “personas” to direct design.
6. A conceptual design direction based on data analyses.
7. Design and prototyping.
9. Data collection and analyses of students’ learning processes in relation to design ideas and prototyping.
10. Presentation of the designs’ prototype to clients and interested parties.

Teacher Design Research grows out of an instructional system design model that has been developed over time in an extended immersive experience (Bannan-Ritland, 2001). The focus of TDR is on meaningful classroom problems that are selected by and negotiated among the teacher design researchers. The problems are investigated by them with the aim of making explicit their current and transforming practical knowledge about the teaching and learning goal. The design process promotes the articulation of teachers’ beliefs and practices. This encourages them to reconsider their own practice in relation to others’ approaches and through that impetus to create an optimal design innovation that will extend beyond their own classroom. Teachers share related theory and research, as well as participate in multiple cycles of data collection and analysis about students’ and teachers’ learning. These cycles prompt design ideas that are grounded in theory, research findings, and the teachers’ own practice. The teachers participate fully in decisions about the design, along with the research team and other interested parties, and about using the innovations in their own and their colleagues’ classrooms. In this manner, the research phase promotes investment and ownership in the outcome of the design, front-loading the diffusion process as the teachers become engaged in the creativity of innovation. The characteristics of TDR can be described as follows:
• Intensive involvement in multiple cycles of integrated design and research during a long-term initiative (e.g., an academic year).
• Collaborative problem solving and decision making during the design phase between the teachers and researchers.
• Intensive, inquiry-based experience.
• A focus on meaningful and significant learning problems generated by the teachers.
• Direct involvement of the teachers and their full participation in the creative decision making entailed in design research.
• Involvement of students, teacher-colleagues, and experts as resources for design research, but the teacher’s practical knowledge remains paramount as a basis for decision making.
• Guidance and support provided by the research team, programmer, and graphic artist who also learn about teachers’ learning and perspectives on innovation in the classroom.
• Teachers’ reconsideration of their own practices as they design an innovation for their students as well as for other teachers and other children.
• Grounding in the literature of cognitive theory and current research on students’ learning as well as teachers’ practical knowledge of students’ learning.
• Understanding that innovation, change, and reform are long-term, ongoing processes with multiple cycles.
• Teachers are treated as design researchers actively involved in contributing to a conceptual design, and the power of the context of their classrooms is recognized as fundamental to design and research activities.
• Teachers focus on contributing to the design and development of standards-based instruction, fostering students’ conceptual learning, and addressing students’ misconceptions, through applied design, where possible.

**Teacher Design Research is Similar to but Distinct from Other Professional Development Approaches Influenced by Design and Research Activities**

Different approaches embodying design and research activities are beginning to emerge in the literature about professional development for teachers. Involving teachers in design has a recent history, which includes such initiatives as teachers-as-designers (Jonassen & Reeves, 1996), teachers’ design of curricula (Parke & Coble, 1997), participatory design of science curricula (Shrader et al., 2001), and more direct applications of design research principles (e.g., Clements, this volume; Zawojewski, Chamberlin, Hjalmanson, & Lewis, this volume). Many of these initiatives consisted of short-term, workshop-like experiences for teachers conducted during the summer outside their job context, but other endeavors are moving beyond these bounds.

Other professional enhancement efforts have shown promise in the development of teacher-generated innovations through curricula design, reflection, and reconceptualization of practice. Lewis et al. (2006: 3) advocate employing the Japanese lesson study approach in a manner that considers the “development of a descriptive knowledge base; explication of an innovation’s mechanism; and iterative cycles of improvement research.” In other work, Zawojewski, Chamberlin, Hjalmanson, and Lewis (this volume) attempt to promote mathematics teachers’ professional development through short-term, classroom-based cycles of design research that strive “to produce generalizable theory about the interpretive systems that teachers use to teach.” Penueel (2006) presented an experience of a long-term codesign of innovations in which the teachers,
researchers, and developers collaborate on the design and evaluation of a prototype. Perhaps the last two examples come closest to the concept of TDR; however, they do not seem to address prominently integrated design and research cycles in which the teachers are full participants in data-driven decision making about the design, helping to steer the direction of the conceptual design and ground it in their practice. TDR also seems to differ from some of these other constructs in that there is a deliberate aim to extend the innovation systemically: (a) beyond the teachers’ classroom by involving teachers directly in the contextual analysis of local, state, and national issues, (b) through consideration and integration of the multitiered perspectives of the research community, scientists, and teacher-colleagues, and (c) through students’ perspectives about the learning issue identified in the design research procedures. Details of the experiences of a group of teachers in this type of TDR activity are given in a later section of this chapter.

Teacher Design Research is Viewed Through a Frame of Diffusion of Innovations

As noted before, TDR does not promote a view of teachers’ professional development as a training problem; rather, it views teachers’ professional development as a problem in the diffusion of innovations (Rogers, 2003). Zaritsky et al. (2003) describe the diffusion of an innovation as a social process, associating the rate of adoption of the innovation as being determined by: (a) the type of innovation decision, (b) the nature of the communication channels diffusing the innovation at various stages in the innovation’s decision process, (c) the nature of the social system, and (d) the extent of the change agents’ efforts in diffusing the innovation. The goal of TDR is to encourage teachers to adapt cognitively their current practice, over time, to more complex and innovative, but still compatible, ideas and practices. The process of adoption takes considerable time. Rogers (2003) claims that the adoption of an innovation involves five distinct processes, which are handled socially:

1. **Knowledge:** coming to learn the existence and function of the innovation.
2. **Persuasion:** being persuaded about the value of the innovation.
3. **Decision:** committing to adopting the innovation.
4. **Implementation:** using the innovation for an extended period of time.
5. **Confirmation:** ultimately accepting or rejecting the innovation.

TDR places the adopter (the teacher) centrally in the diffusion process as a designer and a researcher. The teacher is a part of the team that generates the existence and function of the innovation. The teacher is a part of the persuasion process for himself or herself and for others. The decision to commit is based on the teacher’s observation of what Rogers (2003) calls “observability” and “trialability” processes, except that the teacher (as an adopter) is involved actively in the redesign, based on these processes. Further, the teacher is not implementing an outsider’s product or process; rather, he or she is putting into effect his or her own theories about an intervention as expressed in the (co)designed intervention and is implementing the intervention across a number of generation-and-testing cycles. The teacher’s cumulative decision to accept or reject the innovation is based on multiple design cycles. One of the hopes of TDR’s exponents is that innovations that survive to adoption by the designing teacher(s) are more likely to be adopted by other teachers in similar contexts than innovations that are developed by outside experts.
Teacher Design Research Requires a Long-Term, Intensive Commitment to Teachers’ Learning

The TDR process does not come without costs, commitment, and effort. Changing teachers’ conceptual beliefs and practices is a long-term, intensive process that requires acceptance by teachers. However, analysis of our data suggests that involving teachers in examining their own practices for the purpose of design research over a long period with appropriate resources promotes a high level of engagement and ownership in the development and use of the innovation (Bannan-Ritland et al., 2006). There is also preliminary qualitative evidence that six teachers who participated in TDR reported a shift in their beliefs about teaching and learning. If further research bears this out, TDR and other codesign approaches may hold promise for addressing the perpetual problems inherent in sustaining reform-based innovations in education contexts (see Fishman et al., 2004). However, as Penuel (2006) importantly pointed out, issues of defined roles, accountability, design decision making, time, and expense need to be considered in these forms of complex professional development.

The benefits may outweigh the costs, however, if TDR can promote quality professional development for teachers and can improve the design and fit of classroom-based innovations in which the teachers have ownership and promote in their local contexts. Teacher design research, then, can address Rogers’ (2003) factors of relative advantage, compatibility, complexity, “trialability,” and “observability” through the direct involvement of teachers in the conceptualization, creation, and testing of prototypes that address problems identified in the classroom. Through multiple cycles of data collection, analysis, and design, the teachers become invested in the innovation and promote its testing in their classrooms and its use through their social networks. These natural cycles that take place in design research provoke a necessary, bottom-up approach to innovation and scaling that also may have the capacity to promote learning and change by teachers.

An Illustration and the Preliminary Results of a Teacher Design Research Experience

An initial foray into TDR involved six teachers in the conceptual design of a technology-based prototype that intersected scientific inquiry processes with reading comprehension at the fourth-grade level. This experience was structured deliberately so that it would engage the teachers in inquiry through their participation in an inquiry-based, design research project investigating how students and teachers learn. The teachers and the research team were asked to identify an area in science and to design learning activities pertinent to national and state standards that incorporated iterative integrated cycles of data collection and analysis and the design of a web-based technology system. Some design decisions were a direct result of the teachers’ data analyses; other design decisions were made based on the integration of multiple factors such as teachers’ insight and practical knowledge, as well as pragmatic factors (for a discussion of the process of design research decision-making, see Bannan-Ritland and Baek, this volume). The teachers were supported in their conceptual design activities by the project investigator, who is a professor in instructional design, a team of four graduate research assistants, who included a computer programmer and a graphic artist, and a science consultant.

The remainder of this chapter recounts parts of a comprehensive qualitative investigation into the teachers’ perceptions of the TDR experience and identifies shifts in the
teachers’ beliefs and intentions about scientific inquiry during the experience. The context of the study is reported, along with some illustrative data from one teacher’s participation. These preliminary results are being analyzed further, together with data from the other five teachers, in a comprehensive, cross-case analysis. Follow-up studies are planned for the purpose of collecting additional video observation data from the classrooms of the participating teachers. These new data will be reviewed against baseline classroom video data collected during the first year of the teachers’ involvement in this project (2003–2004) in order to determine any long-term impact on their practice after they took part in TDR.

Participants
Six teachers from four schools in a small school district situated in an urban-suburban area in the mid-Atlantic region of the United States participated in this research. The TDR project consisted of two, nine-credit courses during an academic year that entailed weekly, face-to-face sessions that involved teachers directly in research and design activities and were supplemented by online discussions. The teachers were recruited with the help of the school districts’ science supervisor. Tuition for the courses was funded by the National Science Foundation grant. Five of the participants were elementary school teachers who served in various roles: three as fourth-grade classroom teachers, one as a mathematics-special education resource teacher, and one as a science resource teacher for her school. The sixth teacher was a middle-school reading specialist. The rest of this chapter reports the analysis of data from the experience of one teacher (the science resource teacher) during the academic year of her involvement in TDR. Portions of the data analysis and of interviews with this particular teacher are presented as part of a case study to illustrate the potential of TDR for further research (Glaser & Strauss, 1967; Yin, 2003).

The Teacher Design Research Experience
Generally, the TDR experience followed an emerging process model that attempts to intersect systematic, instructional design processes with rigorous research investigation of cognitively-based theories about teaching and learning and with other perspectives on the design and diffusion of innovations entitled the Integrative Learning Design Framework (see Bannan-Ritland, 2003). As noted earlier, the six teachers described above were involved in two, nine-credit, instructional design courses during the 2004–2005 academic year (August through May) that were designed specifically to investigate teaching and learning issues related to science inquiry and reading comprehension in order to inform the design of a technology system that integrated these processes and concepts at the fourth-grade level. The teachers were involved intimately in the needs assessment process, selecting an area of study (e.g., landform change in geoscience), aligning the direction of the design with state and national standards, reviewing current research in science inquiry, earth science, geological reasoning and reading in science. The year-long experience culminated in the teachers presenting their ideas for the design of a technology-based prototype to the funding agency’s advisory board.

During their TDR experience, the teachers were instructed specifically to consider their prior knowledge, synthesize current research literature, and collectively translate and integrate their practical knowledge, theoretical constructs, earth science content, and research findings into a conceptual design of a technology-based prototype. During the first semester, the teachers were guided initially through a contextual analysis of
their approaches to teaching science, school culture, and obstacles for the integration of science and literacy in the classroom. After much discussion and an interview with a representative from the American Association for the Advancement of Science, learning about the processes of erosion and landform change in earth science was targeted as an area of curricular need that aligned with local, state, and national standards. To gain an informed perspective on this content area, the teachers worked with a geomorphologist who led them through a condensed learning experience about geomorphology that encompassed more than 20 hours of formal instruction and a field learning experience in a nature center next to one of the teacher’s schools. During the second semester, the teachers participated in data collection and analysis of their students’ prior knowledge and reading abilities in earth science, employing a think-aloud procedure, and interviewed colleagues about their perspectives on inquiry science teaching, which informed subsequent design ideas. Toward the latter half of the second semester, the teachers synthesized their learning and practice into a theoretically-based idea for a conceptual design for teaching the processes of erosion that combined an inquiry-based approach to science with reading comprehension skills.

Research Aims

In this exploratory, single-case study, there was a particular interest in seeing how the science resource teacher’s understanding of inquiry, geoscience content, and the intersection of reading and science might change during her TDR experience. There also was considerable curiosity about how she perceived and engaged in the TDR project, her learning through it, and if she found TDR valuable professional development. The theoretical propositions on entering into this study were:

- Participation in a long-term, design research undertaking will give teachers time and space to articulate collaboratively and individually their practical knowledge, beliefs, and understanding about inquiry science; about connecting inquiry science, reading, and students’ learning; and the obstacles to success in this endeavor.
- The teachers’ involvement in design research will result in changes in their perceptions of scientific inquiry and in their perceptions of their level of knowledge of geoscience content, and an increased awareness of the linkages between science and literacy.

The initial assumptions were that, in a rare collaborative context, the teachers’ involvement in design and the design research process might prompt their reflection on, and explicit articulation about, integrated beliefs and classroom practices. It was conjectured that focusing on integrated design and research tasks to produce a conceptual design collaboratively might have the potential to prompt the teachers to reconsider their own practices, practical knowledge, and knowledge of pedagogical content. Although it was thought that the TDR experience would elicit some changes in the teachers, it was unclear what they would be, both individually and collectively. Essentially, these teachers were attempting to generate an inquiry-based learning environment based on the integration of their practical knowledge, research, and collaborative insight while engaged in a challenging, inquiry-based learning context of TDR. In this complex, multitiered, collaborative experience, it was not known what to expect as an outcome.
Data Sources

The data included: (a) many interviews with the teachers, (b) video-recordings from weekly class sessions (four hours across two, 16-week sessions, for a total of 128 hours of video data), (c) online discussions, (d) online journal reflections, (e) individual, teacher-produced artifacts (individual concept maps, transcripts of interviews with colleagues, data analyses, students' think-aloud protocols, transcriptions, and analyses), (f) collaborative, teacher-produced artifacts (concept maps from brainstorming about design), and (g) research team’s memorandums and multiple surveys related to teachers’ practice, content knowledge, and design knowledge. Individual interviews were conducted with the teachers approximately one month into the nine-month experience, during the fourth month, and at the conclusion of the experience.

Case Study: Jennifer

To explore the potential of TDR for further research, a case study of Jennifer’s experience is presented here. Sections of the interviews with Jennifer at the beginning, midpoint, and conclusion of her TDR experience are highlighted to illustrate how TDR may address the desired characteristics of teachers’ professional development. The interview data are presented to draw attention to these characteristics and, it is hoped, to spark interest among educational researchers to investigate further the impact of TDR efforts on teachers’ professional development.

Jennifer was an elementary science teacher and also provided professional development for teachers in her school. What was notable in Jennifer’s case study (as well as informed the preliminary analyses of the case studies of the other teachers), was the shift in her perspective of inquiry-based science from the beginning to the middle to the end of her TDR experience. She articulated her initial and reconceptualized understanding of scientific inquiry as well as her shifting view of the intersection of reading and science to provide some evidence for the viability of TDR to address the necessary components of teachers’ professional development.

Jennifer’s Changing Perspective of Scientific Inquiry: Teachers as Active Learners who go Beyond their Existing Orientations to Adapt to New Situations

Putnam and Borko (1997; 1281) advocate that the context for teachers’ professional development “must take into account and address teacher knowledge and beliefs” because “what teachers know and believe will influence their interpretation and enactment of any new ideas for teaching.” The TDR experience begins with a collaborative investigation and an explicit articulation of teachers’ current practice and beliefs related to the teaching and learning issue identified. Investigating scientific inquiry and its intersections with reading comprehension were posed as the teaching and learning issues for Jennifer and the group of teachers involved in this TDR experience. During her participation, Jennifer’s beliefs and practical knowledge about inquiry seemed to change.

Initially, Jennifer’s view of scientific inquiry could be described as conflicted. She attempted to integrate her definition of inquiry, which she described as “coming up with different results and taking different paths” in science, contrasted with a traditional, structured, step-by-step version of the scientific method, which she regarded as being promoted by the curricular materials and her colleagues. In defining inquiry,
Jennifer placed significant emphasis on student’s questions and aligned her perspective with her school’s philosophy of a constructivist-based, “hands-on, minds-on” approach. Jennifer said that she advocated teaching inquiry with her colleagues with a clear sense of the steps to follow in the scientific method. In her existing mental model of inquiry, the idea of hypothesis testing was paramount. Paradoxically, the focus on the algorithmic nature of this method served to constrain both Jennifer’s view of scientific inquiry and her desire to allow for different paths for students traversing inquiry-based experiences in science lessons. This created tensions between the “hands-on” perspective, which supported following set procedures, and a “minds-on” perspective, which permitted students to follow their interests and curiosity, both of which were prominent in her initially articulated knowledge and beliefs about science inquiry.

In the TDR cycles, Jennifer was required to face these tensions directly. At the midpoint after four months, her understanding and representation of inquiry seemed to shift from following algorithms and testing hypotheses to a greater emphasis on process skills such as observing, analyzing data, and writing descriptions. Now, Jennifer saw the usefulness of students’ questions, not for their own sake but for the purpose of promoting the students’ “ownership” of the scientific process. At the middle of her TDR experience, Jennifer said she had a greater appreciation of science as a collaborative, nonlinear process. Her view of classroom inquiry had expanded to incorporate different ways of investigating scientific phenomena.

By the end of her nine-month TDR cycles and experience, Jennifer had moved away from a view of classroom science inquiry as “recipe following” for hypothesis testing toward a flexible rich representation of the scientific inquiry process, both for herself and for her students. She believed now that science involved experiential learning that can prompt questions that are not always stated as formal hypotheses. Jennifer reconceptualized her understanding of the scientific inquiry process and expanded her definition beyond mere experimentation to include observation and other forms of inquiry. Her emphasis on students’ questioning had changed as well because she saw now the role of questioning as an ongoing cyclical process in scientific inquiry, not as a means to an end in the classroom. At the conclusion of her participation, Jennifer seemed to express the desire to adapt her practice to place additional emphasis on using resources beyond the classroom to inform scientific questioning and investigations such as books, the internet, experts, and other resources of the scientific community such as the U.S. Geological Survey and the American Association for the Advancement of Science. After the TDR experience, Jennifer seemed to grasp the idea of science inquiry as a community phenomenon incorporating many different resources, rather than as a simplistic procedural process. Jennifer’s new definition of scientific inquiry was:

I see that a lot of times it begins with an experience, and a question is raised. I’ve also, and this has changed for me, always felt that you had to make a hypothesis, and I still want kids to make predictions and hypotheses, but I also know that you could be wondering and you don’t always have, and scientists don’t always have an exact hypothesis. So I may be being a little more flexible in that. I see that they can find the answers to their questions not only by setting up an experiment, but by asking experts, looking on the internet, looking in books. I see the importance of community in inquiry and running your ideas by others, talking about them as you work, and up here I had the importance of presenting and sharing. And it doesn’t always have to be a formal presentation, it could be just in your little group, you know, share or have a jigsaw—one person share with another. I also see that it’s ongoing, that as you’re sharing, you come up with more questions, and as you’re
investigating, you come up with more questions. I think the challenge might be that you don’t just get really off track. [laughter] So that’s my definition of inquiry.

During her TDR experience, Jennifer’s knowledge and beliefs about scientific inquiry seemed to change dramatically from her initial stance. Through her participation in TDR, she was forced to adapt to new situations as a teacher-design-researcher involved in data collection, analysis, and design, which demanded that she confront new ideas about scientific inquiry. This provided a context where she had to grapple with her own understanding of pedagogy in science along with other perspectives from her peers, researchers, and the literature. She had to integrate her everyday, action-oriented, person- and context-bound, practical knowledge with the more formal, scientific knowledge that she explored through experts and other resources. Interestingly, Jennifer’s expanded view of inquiry seemed to be a result of her inquiry-based activities in design research. Jennifer’s TDR experience permitted her to examine her own beliefs, knowledge, efficacy, and efficiency in teaching science in an inquiry-based manner in order to contribute to designing new approaches for the fourth-grade classroom. Along the way, she reconceptualized her beliefs, moving beyond the often articulated perspective that scientific inquiry relies on “hands-on and minds-on,” scientific methods-based, procedural directives.

At the end of the TDR experience, Jennifer was able to stand back and analyze her own progression and teaching as they related to scientific inquiry in this way:

I think that, I didn’t really know what inquiry was. I mean, I hear, I say inquiry-based, and I think of it as doing hands-on. I thought that was inquiry. And from this, that has changed. Yes, a lot of it is hands-on, but it’s more a way of thinking and it’s also that the whole ongoing process has changed. As I said earlier though, I haven’t implemented as successfully as I would like to.

**Jennifer’s Reconsideration of How She Teaches Science: Expanding the Frames and Questioning her Practice**

Jennifer’s expanded understanding of the strategies, skills, and reasoning involved in scientific inquiry after her involvement in TDR allowed her to see more possibilities in her teaching practice. However, she was frustrated by not being able to enact all that she was learning at that time. Despite this frustration, she was able to integrate her experiences with those of her peers and the scientist, the formal research, and theory-based information with her everyday teaching knowledge. This integration was rooted firmly in, and represented by, her classroom practice. This gives credence to Cochran-Smith and Lytle’s (1993) approach to the development of teachers’ knowledge in a TDR context as including the development of knowledge for practice, in practice, and of practice. This is evidenced by Jennifer’s significant reflection on, and reconsideration of, her teaching practice in science that occurred during her participation in TDR. While planning her next science lesson, she remarked:

When I was planning it, I thought I’m trying to convey the content, but am I just trying to fill them up and doing some experiments or am I letting them ask questions? And I thought, if I’m only going to have this much time with them, how much time can I let them have to explore their questions? I think it [the TDR experience] has made me question whether I am a good teacher or not, and if I am teaching in the best way.
Cochran-Smith and Lytle (ibid.) state that “the knowledge teachers need to teach well emanates from systematic inquiries about teaching, learners and learning, curriculum, schools and schooling. This knowledge is constructed collectively within local and broader communities” (p. 274). The TDR experience required Jennifer and her colleagues to explore scientific inquiry processes systematically through integrated research and design cycles, which seemed to result in expanded frames for their teaching practices, although not without some cognitive dissonance and struggle. Jennifer continually mapped others’ perspectives that were articulated in the design research process back to her own, and her participation in the design of the classroom innovation seemed to prompt a natural process of questioning her own practices.


The TDR experience maps to Hammerness et al.’s (2005a: 385) framework for teacher’s learning in communities that includes: (a) developing a vision for their practice, (b) a set of understandings about teaching, learning, and children, (c) dispositions about how to use this knowledge, (d) practices that allow them to act on their intentions and beliefs, and (e) tools that support their efforts. Jennifer’s developing vision of scientific inquiry meshed with her teaching practice. Her understanding of children’s geoscience reasoning and the collaborative process in TDR informed her knowledge about teaching, learning, and children. The juxtaposition of scientists’ and teachers’ dispositions, practices, and tools promoted in TDR created the space for Jennifer to progress and act on her own understandings, intentions, and beliefs about scientific inquiry during her TDR experience. By observing and examining the tools and processes of a geoscientist, Jennifer was able to gain a solid foundation in the earth science content of erosion processes, as well as to transfer her understandings of these tools and processes into the classroom to benefit her students.

Jennifer’s perception of her professional development was centered on her personal learning processes, which evidenced some transformation in her thinking about her teaching as well as in her appreciation for the TDR approach in promoting teachers’ learning. During the TDR experience, she felt that she learned a significant amount of earth science content and the general importance of teachers’ foundational knowledge for teaching, learning, and design. Another important insight for Jennifer was that she felt that after experiencing a TDR process, any type of curriculum design project should integrate or address learning theory. By this statement, she implied that many efforts in this area do not address directly students’ and/or teachers’ cognition, which she felt was crucial and catalytic to the TDR experience. In general, Jennifer described her participation in TDR as “a tremendous learning experience” that was “excellent,” “positive,” “valuable,” and “invigorating.” While participating in TDR, Jennifer described herself as highly motivated and said she felt that “the experience was perfectly designed for me.” The inquiry-based, generative, creative, but ambiguous nature of uncovering and exploring significant teaching and learning issues seemed to map well to Jennifer’s learning style, but, more importantly, promoted her own constructed understanding and knowledge of scientific inquiry and her strong intention to incorporate them into her practice.

Theorists involved in the professional development of teachers speak to the importance of engaging with subject matter in new ways by wrestling with pedagogical problems, issues of students’ learning, and a deep understanding of the subject matter content (Putnam & Borko, 1997: 1226). The notion of adaptive expertise also aligns
with Jennifer’s engagement with new scientific content and processes integrated with the problems and potential she dealt with in the classroom everyday to hold her students’ attention successfully. At the end of her TDR experience, Jennifer’s expertise about students’ learning in geoscience was informed greatly by intersecting research-based knowledge with a geoscientist’s modeled practice and a teacher’s applied practice. She was able to integrate all of this information successfully to design and create new lessons for her students, thereby promoting her adaptive expertise by adding continuously to her knowledge and skills in this area. As evidence of the progression of her adaptive expertise in the area of geoscience, she offered the following from her online journal at the conclusion of the TDR experience:

After I received Randy’s e-mail I decided I should go to Great Falls and do some firsthand research myself (o.k. it was a nice day and I needed a break from my PowerPoint). I talked to a ranger, Miguel Robinson, while I was at Outlook No. 2 at the Falls. He could not answer all my questions. I left my card with him, and he said he would have the park geologist call me. We hiked along the River Walk trail. The potholes are fascinating. I think our students would really get into the force of water in a whirlpool-like action creating these holes in the rocks. You can readily see the evidence that water once shaped the land at this location that is now high above the river.

Jennifer’s content knowledge in geoscience and her questions challenged a park ranger’s expertise, and the above excerpt demonstrates her formal knowledge in this area integrated with the applied practice of how she might translate that knowledge for the students in her classroom. If Schwartz et al. (2005) are correct, then the two dimensions of expertise in teaching, innovation and efficiency, may be supported by a TDR approach for professional development. Through her experiences in TDR, Jennifer’s knowledge of geoscience content became accessible and efficient and promoted her ability to participate in a design innovation for the project, with positive residual effects in her classroom.

Teachers’ knowledge and professional development seem to be promoted by their involvement in design research. Cycles of integrated design and research in a specific content area moved Jennifer out of her former understanding of scientific inquiry and caused her to reconceptualize her teaching practice. The collaborative nature of TDR provided a safe, trusting, and supportive environment for creative innovation and change to occur. Hammerness et al. (2005a: 361) stated it this way:

Lifelong learning along the innovation dimension typically involves moving beyond existing routines and often requires people to rethink key ideas, practices and even values in order to change what they are doing. These kinds of activities can be highly emotionally charged and the capacity to consider change without feeling threatened is an important ability.

This type of change requires professional development experiences beyond the typical training made available to teachers. TDR experiences may provide the context for teachers’ adaptive expertise, efficiency, and innovation to flourish and motivate them to engage, re-engage, and transform their practice.
Conclusions

Involving teachers in the ambiguous and complex environment of design prototyping and research cycles places them in situations of fostering their own “adaptive expertise,” where they are required to articulate their practical knowledge, integrate and generate new ideas about teaching, and go beyond their current practices to add continuously to their knowledge and skills (Darling-Hammond & Bransford, 2005; Hatano & Oura, 2003).

Engaging teachers in cycles of data collection and analysis that inform prototyping and design decision making promotes a leveling of the field in building trust and collaboration. The researcher must be willing to share power to promote mutual trust and learning among all concerned in order to generate new ideas and facilitate change in the classroom. Generally, teachers’ practical knowledge is not valued in many research contexts, but if it is placed in a position of ultimate importance for change and the diffusion of innovations to occur, then reform becomes possible. Teachers also need to be open to new ideas and new ways of doing things, but they are intimately involved in creating those ideas. The teachers participating in these studies took very seriously their role of building something that other teachers and students would use. Fundamentally, TDR provides the context to learn and to make design research decisions with those who will be responsible ultimately for making change happen in the classroom.

Many levels and directions of learning are being explored in the TDR model. Researchers learn about teaching, teachers learn about research, and everyone learns what might and might not work in the classroom, as they proceed through numerous cycles of data-driven, design decision making, prototyping, and streaming of ideas. The collective process of integrating multiple sources of information to improve design research promotes the honoring of all sources of information from both research and practice.

In educational reform efforts, we typically are asking teachers to adopt new practices that researchers create, perceive, and demonstrate as valuable and effective. Asking teachers to replace their current practices in which they are invested and adopt new ways of doing things seems a difficult path. Teachers engage directly in the conceptualization of integrated design and research and carrying out such cycles with their students and their colleagues. This brings to light a broader view of their challenges while providing collaborative support in decision making about teaching practice and innovation. The TDR process naturally provokes the articulation and reconsideration of beliefs about teaching practice when attempting to generate collaboratively a new practice or design. The TDR context may provide an extended timeframe to integrate teachers’ practical knowledge with research-based practices and to generate innovative design ideas that will improve learning. This long-term process also may promote the ownership and commitment necessary for teachers to consider changing their long-held beliefs and practices, as well as to work toward the local diffusion of new approaches through teachers’ social networks.

Although much more work needs to be done in the research and development of TDR, it potentially could be applied to many different instructional issues. Bringing teachers, researchers, subject matter experts, graduate students, and developers together sparks rich investigations and discussions of teaching and learning that have the capacity to promote change at local levels. Software development and publishing firms that produce teaching and learning materials also may benefit from a TDR approach through improved products. Ideally, participation in these interdisciplinary teams may improve research as well because much information is lost in the design...
process (e.g., in interviewing learners and other interested parties about teaching and learning issues or testing different approaches to the design of software); if it were captured in more formal ways, it could inform research directly.

The potential benefits of TDR are many, including multitiered, multidirectional learning by researchers, teachers, and students as well as the generation of improved processes and products that embody innovations that can diffuse from the local level through teachers’ social networks. Perhaps it is time to revisit the top-down, didactic, traditional models of teachers’ professional development and move toward engaging them in challenging, creative, generative, design research processes that may foster their learning and change. If we advocate learning contexts for students that focus on:

- strategic and flexible use of knowledge
- mediating learning as it is constructed
- taking on the role of active constructor of meaningful cognitive networks that are used during problem solving
- defining and representing problems; transforming existing knowledge into one of many possible solutions
- presenting conditions in which failure is accepted as part of learning
- valuing highly self-regulation or cognition
- other students being viewed as resources for learning

Then why would we not want to construct these types of learning environments for teachers, too (Putnam & Borko, 1997)? Despite its challenges and costs, TDR offers a viable new approach to professional development that has the potential to provide teachers with these important features for their learning so that they can serve our children in the best possible manner.

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Note

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