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Informing Design Research: Learning From Teachers' Designs of Social Infrastructure

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The design research methodology as it has currently developed centers on the creation of *existence proofs,* an important first step. What is needed then are the next steps of expanding the methodology to address the design problems of practical implementation prior to the steps involved in scaling up these designs. This article contributes to such an expansion through developing a systematic approach to learning from teachers' enactments of educational models. Design research focused on practical implementations by teachers can create knowledge regarding critical change processes, thus helping to create a theory of trajectories of change, or "implementation paths" (Bielaczyc & Collins, 2006a; Collins, Joseph, & Bielaczyc, 2004). Here I propose using the Social Infrastructure Framework (Bielaczyc, 2006) to analyze the design of classroom social structures by developers and teachers in order to better understand their implications for constructing implementation paths. The analytic technique is exemplified through a case study involving a particular team of teachers who worked over the course of several years to adopt a knowledge-building communities approach (Bereiter, 2002; Scardamalia, 2002; Scardamalia & Bereiter, 1991, 1994). The results are used to discuss implications for the methodology of design research.

Design researchers study interventions in practice, with the dual goal of progressively refining the design of an intervention itself and the theories of learning and teaching that inform the design (e.g., Barab, 2004; A. L. Brown, 1992; Collins, 1992; Kelly, 2003; Sandoval & Bell, 2004). It is possible to refine educational interventions without developing a deep understanding of how and why things work. However, the design research methodology is meant to provide a means of constructing robust theories of why certain practices are effective

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and how learning occurs in context. Through analysis and theorizing, design researchers work to determine the critical elements of an intervention and how their combinations make for effective learning environments. The development of the methodology of design research is still in its early stages. This article, along with companion articles (e.g., Bielaczyc, 2006; Bielaczyc & Collins, 2006a, 2007; Collins, Joseph, & Bielaczyc, 2004), is meant to contribute to the ongoing conversation about the goals and methods of the design research community.

A critical objective of design research is developing the key principles of the intervention for both the purposes of advancing theory and the practicalities of dissemination (A. L. Brown, 1994). Cole (2007) described how it is important that "the researchers continuously attempt to formulate whatever principles appear to be essential to the operation of the system, expanding and modifying the set as they go along" (p. 80). Over time, the research may result in the design of an intervention that has reached a point of stability, has a recognizable identity, and has been shown to lead to desired learning outcomes. Often, the next step involves a push to scale up these designs in order to bring innovative reforms to schools. However, my goal here is to problematize such next steps.

Most of the K–12 educational studies carried out as design research have focused on contexts in which the developers of an educational intervention have been the agents overseeing the local adaptation into classroom practices. The work focuses on the design problems of an *existence proof*—how to create a design that meets the desired objectives along with an explanation of why the design works. This is indeed critical but not sufficient for the design problems of *practical implementation*—how to bring this innovative design to life in a classroom without the support of the developers along with an explanation of why such implementations work. As A. L. Brown (1992) stated,

> Historians tend to be pessimistic about educational reform (Cuban, 1984, 1986, 1990), an attitude of "la plus ca change" (Cohen, 1989) prevails. The argument is that successful interventions are a chimera or at least are extremely fleeting and fragile, not readily transportable to settings outside the innovator's control. Because of this skepticism, it is extremely important for the design experimenter to consider dissemination issues. It is not sufficient to argue that a reasonable end point is an existence proof, although this is indeed an important first step. (p. 171)

The design research methodology as it has currently developed centers on the creation of existence proofs, an important first step. What is needed then are the next steps of expanding the methodology to address the design problems of practical implementation prior to the steps involved in scaling up these designs. The purpose of the present article is to contribute to such an expansion through developing a systematic approach to learning from teachers' designs in carrying out classroom implementations of a given intervention.

I situate this work within the continuing evolution of the design research methodology. I also introduce the Social Infrastructure Framework (Bielaczyc, 2006). In Bielaczyc (2006), I detailed how the Social Infrastructure Framework can serve design researchers as a tool for both design and analysis. In the present article the framework facilitates a new analytic approach intended to support the next steps of the design research process after the creation of an existence proof. The analytic method focuses on design research involving educational models, specifically contexts in which a stable model has been established and the interest is in making the model "transportable to settings outside the innovator's control" (A. L. Brown, 1992, p. 171). In order to gain a deeper understanding of the workings of this analytic approach, I ground its presentation in an actual case involving a well-known educational model, Knowledge Building Communities (Bereiter, 2002; Scardamalia, 2001, 2002, 2004; Scardamalia & Bereiter, 1991, 1994). The article concludes with a discussion of the broader implications for design research.

CONTRIBUTING TO THE DEVELOPMENT OF DESIGN RESEARCH

The design research methodology is often cited as beginning with two influential papers by A. L. Brown (1992) and Collins (1992). In Bielaczyc and Collins (2007), my coauthor and I also described design research approaches found in Roland Tharp and Ronald Gallimore's earlier Kamehameha Early Education Project (1979, 1988). Confrey's (2006) chapter in the *Cambridge Handbook of the Learning Sciences* provides a comprehensive history, including much earlier influences. The past decades have seen a burst of empirical work, theoretical treatises, and journal special issues devoted to the topic (see, e.g., Barab, 2004; Barab & Kirshner, 2001; Kelly, 2003; Sandoval & Bell, 2004), as well as the publication of the *Handbook on Design Research* (Kelly, Lesh, & Baek, 2008).

Many researchers have contributed to clarifying the standards and practices of design research, with the aim of developing a coherent methodology that can guide design researchers. The history of science suggests that a nascent research community, such as the design research community, takes years to come together to develop common standards and practices. Such processes of refinement are supported through historical analyses, methodological clarifications, critiques, and identification of areas in need of further work. For example, in their Editor's Note in the *Journal of the Learning Sciences,* Sadhana Puntambekar and Bill Sandoval (2009) described what they see as several "compelling issues for the development of design research as a methodology" (p. 323), such as exploring the tensions between specific contexts and issues of generalizability, refining processes of theory development, and fleshing out the epistemological foundations. In an effort to expand the scope of the methodology, Penuel, Fishman, Cheng, and Sabelli (2011) have proposed broadening design research from its predominant focus on

classrooms to the level of educational systems in order to better understand the scale-up of designs "within a complex institutional ecology" (p. 331).

All of these efforts serve to detail and deepen researchers' understanding of the problem space of design research. In the work undertaken in the present article, I limit my focus to a particular type of intervention within this larger problem space. My work centers on the design work involved in the development of educational models. Although not all design research results in the development of educational models, the community has developed many examples, including Fostering Communities of Learners (FCL; A. L. Brown & Campione, 1990, 1994, 1996), Knowledge Building Communities (Bereiter, 2002; Scardamalia, 2001, 2002, 2004; Scardamalia & Bereiter, 1991, 1994), Fifth Dimension (Cole & the Distributed Learning Consortium, 2006), and the Kamehameha Early Education Project (Tharp & Gallimore, 1988). However, there remains much to be learned beyond the creation of existence proofs. One particular and pervasive challenge concerns how to support teachers in bringing such models into existence within their own classrooms, especially when the current classroom context is very different from the educational context conceptualized by the model. My interest is in whether it is possible to design implementation approaches that assist in navigating the needed transitions, what my colleagues and I term *implementation paths* (Bielaczyc & Collins, 2006a; Collins et al., 2004). Toward this end, I propose a method for learning from teacher enactments of a given model and consider how it can help contribute to the next steps in the design research process.

Extending Design Research Beyond Existence Proofs of Educational Models

Similar to Ann Brown (1992; see quote above), Janet Kolodner (2006), as part of a panel on the learning sciences and the future of education, called for developing a more robust understanding of how to support teachers in enacting educational models in contexts outside of the original design research efforts. Kolodner argued that although the existing research had contributed greatly to an understanding of what works well to promote learning and participation in knowledge communities (citing work such as Scardamalia and Bereiter's *Knowledge Building,* A. L. Brown and Campione's *Fostering a Community of Learners,* Kolodner's *Learning by Design,* and Mioduser and Levy's *Design-Based Kindergarten*), what was needed was a deeper understanding of "How do we get there?" The calls by Brown and Kolodner centered on advancing both practical dissemination and theory development: (a) designing ways to bring such innovations to life in contexts outside of the developer's control and (b) constructing explanations of why such implementations work.

The critical issue to understand about implementing educational models is that the focus is not on introducing a new curriculum or technological artifact into

the workings of an educational setting. Instead, the intervention is fundamentally about reconceptualizing the workings of the settings themselves. One way to address the question of "How to get there?" is to construct entirely new schools or contexts meant to embody the model (e.g., see the schools described in Tharp & Gallimore, 1988, and Rogoff, Turkanis, & Bartlett, 2001). Another way is to develop the means for supporting shifts within existing educational settings. The analytic method developed in the present article contributes to the latter approach. The method is grounded in classroom enactments of the educational model in settings initially different from the "goal state" of the model. In describing the analytic approach, I show how it can facilitate the construction of *implementation paths*—the design of a trajectory or set of phases that teachers and their students can traverse in order to navigate the desired shifts. The goal of such design research is both to undertake the creation of supportive paths and to deepen understanding of critical change processes.

In focusing on teachers' designs, the analytic method presented here also contributes to research on the enactment of classroom reforms and teacher adaptation. Research in these areas has evolved over the years, as a deeper understanding develops of organizational change factors and processes, the roles of the varying actors of change, and the potentials of new media (e.g., Cobb, Zhao, & Dean, 2009; Evans, 1996; Fullan, 2007; Linn & Hsi, 2000; Simon & Tzur, 1999; Songer, Lee, & McDonald, 2003). The literature maps out various dimensions involved in teacher enactments of classroom reforms through investigating a spectrum of issues and tensions, including an implementation's fidelity to the intent of the reform, local variations, teacher knowledge and capacities, and what counts as success (e.g., M. Brown & Edelson, 2003; Hickey & Zuiker, 2003; O'Donnell, 2008; Penuel & Means, 2004; Reiser et al., 2000; Songer et al., 2003). Recent investigations have also centered on designing means for supporting teachers in carrying out classroom implementations, such as educative materials (e.g., Ball & Cohen, 1996; Davis & Krajcik, 2005; Lin & Fishman, 2004), teacher communities (e.g., Barab, Barnett, & Squire, 2002; Fishman & Davis, 2006), and professional development geared toward instructional design and adaptation (Penuel & Gallagher, 2009).

The introduction of transitional steps as part of implementation paths is intended to add a dynamic and longer term perspective to the literature on teacher enactments of designs. The current literature tends toward considering a teacher's adaptation in terms of an intended and a *single* enacted design, examining issues of fidelity and other characteristics that tend to be determined in the short term. This may be a function of the literature focusing on particular curricula or technological artifacts intended to be incorporated into the workings of the local settings for only a short period of time. However, enacting educational models involves pursuing long-term change. Taking a more dynamic perspective allows for a consideration of teacher approaches that address initial local constraints and needs,

which, in turn, leads to change, resulting in new local constraints and needs that permit teachers to then enact different approaches, in an iterative fashion, thus forming a path toward implementation of the model.

Barab and Luehmann (2003) underscored how there is much to be learned in linking investigations of teacher enactments as part of design research:

> On one level, an outcome of an effective design experiment is to develop the curricular intervention; that is, the curricular intervention that has been modified to such a degree that it will work most usefully in the classroom. On another level, the desired outcome is a better understanding of the range and diversity of local needs as well as the necessary adjustments teachers make in order for the innovation to be useable and effective in a particular context. The implication to be derived from these articles is that useful design work never under-respects the role of the teacher—the goal is not to develop teacher-proof curriculum. Instead, each classroom implementation can be thought of as an important leg in the overall design experiment, innovating and implementing the curriculum in a manner that best fits each specific context. (pp. 459–460)

Extending the design research methodology to include teacher enactments can help advance an understanding of the design implications of various implementation contexts "as opposed to a completed trajectory that was overseen by the designer" (p. 461). The analytic method developed in the following sections provides an approach for more systematically working with the rich design information generated by teachers.

Researchers and other educational stakeholders may take issue with my proposing an analytic method framed in a way that (a) distinguishes design work on an existence proof from design work on next steps and (b) positions an educational model as a goal state. For example, in his keynote talk and associated paper for the 2008 International Conference of the Learning Sciences, Yrjö Engeström (2008) critiqued design researchers for what he saw as a commitment to "notions of perfection, completeness, and finality" (p. 4) and perspectives that were framed too linearly. However, I would argue that the processes of design research are not bound in this manner. Creating and refining designs is viewed as a means for understanding, not an end. Multiple products may be developed, but the product represents a *point of stability* in the progressive improvement of the design rather than a point of finality and perfection. When I describe how certain innovations created through design research can become specified in terms of an *existence proof of an educational model,* the model is taken to represent a point of stability, not finality. That is, the model is specified in enough detail to be adopted by others outside of the development efforts, but the model itself still continues to be refined as part of an evolving design research process.

The framing proposed here is not intended to simplify to the point that it belies the rich complexity in the interactions among theory, design, and practice in the

process of carrying out design research. Furthermore, the analytic method is not meant to be used in isolation but rather is to be seen as part of the spectrum of tools available in "the learning scientists' toolkit" (Barab, 2006). The nature of design research is that boundaries are never strictly delimited, and the designs, theories, and implementations are inextricably interwoven. Through investigating contexts developed by design, the central aim is to contribute to a multilayered understanding of learning and teaching; of agents, actions, and interactions; and of systems. The proposed approach is intended as one means of contributing insights to this multilayered understanding.

TOWARD THE DESIGN OF IMPLEMENTATION PATHS

Bringing an innovative model into classrooms involves transitions. If teachers are new to the model, then there is a trajectory of change that teachers themselves must undergo (e.g., Messina, 2001; Shulman & Gamoran Sherin, 2004; Simon & Tzur, 1999). If teachers are experienced with implementing the model, but their students are coming from classrooms that operate quite differently, then there is a trajectory of change that students must go through (e.g., Bielaczyc & Blake, 2006; Herrenkohl & Mertl, 2010). The concept of implementation paths is based on the assumption that such change trajectories may be best supported by a set of differentiated design elements that help scaffold participants from their initial entry point toward a more robust implementation of the desired model. Clearly, there is no expectation to produce a step-by-step procedure for classroom implementations. However, extending the design research process to learn from teacher enactments may yield important insights into ways of better supporting necessary shifts.

Constructing a Dialectical Relationship Between Developers' and Teachers' Designs

Here I propose a systematic approach to learning from teachers' designs in carrying out classroom implementations of a given educational model. The method permits a deeper understanding of the affordances and constraints of various implementation contexts and a consideration of possible implementation paths. The approach involves constructing a dialectical relationship between developers' and teachers' designs of social infrastructure.

The analytic method focuses on the design decisions that teachers make in order to implement the model. The approach involves conceptualizing two layers of design: the design as conceived by the developers of the model and the design as conceived by teachers adapting the model to the local context of use. The claim is that investigating the interplay between the layers in this double layer of design

provides a valuable, but as yet underutilized, source of data for informing design research.

It should be noted that simply declaring the usefulness of investigating the process of adopting a model as a double layer of design does not necessarily mean that developers and teachers view themselves as complementary agents in the design process. In fact, a reviewer of an earlier version of this article commented that it might be too strong a claim to say that teachers are designers. However, teachers do indeed make design decisions involving how to organize the instructional setting (refer to Penuel & Gallagher, 2009, for an overview of shifting perspectives of the role of teachers in design). The double layer of design conception is meant to frame the process in a way that validates both developers and teachers as design agents and emphasizes that the flow of design knowledge should be bidirectional. But researchers need to deepen their understanding of this double layer of design. It is not simply an issue of translation into use. Teachers must negotiate between the goals and principles underlying the model and the realities of their local contexts. It is through examining the nature of this negotiation that design researchers can advance their understanding.

Furthermore, characterizing the process as a double layer of design is proposed as a useful framing for purposes of analysis. It is critical to underscore the fact that investigating the interplay between a given intervention and a teacher's designs is *not* meant to imply that design researchers adopt an approach based on an "overlay model" in which one is looking at how closely a novice conception approaches that of an expert conception (Carr & Goldstein, 1977). Instead, comparing the designs and investigating the underlying reasons for similarities and differences permits the teasing out of key issues. My aim is to contribute a method for constructing a dialectical relationship and a means of incorporating advances in understanding into the broader design research dialogue.

There are many elements that could be examined across the double layer of design. Because the design work that I am addressing concerns the design problems of classroom implementations, it is important to use an analytic framework that permits an examination of a variety of critical design commitments. That is, classroom implementations involve a broad spectrum of design commitments, including the creation of a particular classroom culture, the means for participating in shared practices, and specifications of other social and technical elements. Given this need, and drawing from the historical literature on technology-based innovations in classrooms (e.g., Bereiter & Scardamalia, 1992; Bruce & Rubin, 1993; Bruckman & De Bonte, 1997; Schofield, 1997; Sheingold, Hawkins, & Char, 1984), I previously developed the Social Infrastructure Framework in order to make explicit the various elements of classroom social structures impacting a design (Bielaczyc, 2006). Here, I exemplify the usefulness of this framework by using it to formulate the critical dimensions to be investigated in the double layer of design.

Investigating Developers' and Teachers' Designs of Social Infrastructure

The Social Infrastructure Framework highlights four dimensions of classroom social structures that influence the type of learning environment created with technology-based tools:

1. The *Cultural Beliefs Dimension* refers to the mindset that shapes the way of life of the classroom. Such beliefs include the ways in which knowledge and learning are conceptualized, students' and teachers' social identities, and how technology-based tools are perceived.
2. The *Practices Dimension* concerns the ways in which teachers and students engage in both online and offline learning activities relating to the technology-based tool. This includes issues such as whether students work individually, in groups, or both and how such groupings are organized. It also includes the various roles a teacher assumes in using a technology-based tool with his or her students. The norms and structures of these learning practices have implications for students' level of engagement, sense of autonomy, and ability to transfer what they learn to other contexts.
3. The *Socio-Techno-Spatial Relations Dimension* refers to the organization of physical space and cyberspace as they relate to teacher and student interactions with technology-based tools. The various arrangements among humans, computers, and space within a particular classroom context impact the dynamics of the learning environments created. This dimension influences accessibility, connectivity, and communication among students and teachers.
4. The *Interaction With the "Outside World" Dimension* refers to the ways in which students interact, online and offline, with people outside of their immediate classroom context. This dimension influences students' motivation, presentation skills, and ability to communicate with others.

Although they are listed here separately, these dimensions of social infrastructure are interdependent. In fact, in the Social Infrastructure Framework, cultural beliefs are posited as a substrate for the interactions (see Figure 1).

Table 1 (from Bielaczyc, 2006) provides more detail on the elements of the Social Infrastructure Framework and introduces 14 subdimensions that provide further specification of the design decisions involved in each of the four dimensions. The framework is not meant to be a rigid checklist but rather a guide to critical design elements to be considered in creating the relevant social structures in support of an educational model.

The Social Infrastructure Framework can be used to systematically characterize the elements in the double layer of design. Data sources concerning both the developers' and teachers' specifications and implementations of the model must

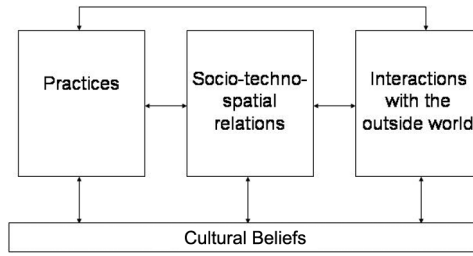

FIGURE 1 The Social Infrastructure Framework as a system of interactions.

be collected in order to create robust design specifications. Analyzing how the developers and the teachers approach the design decisions related to each of the dimensions of the framework creates a 14×2 *parallel-design matrix* (i.e., simplistically conceptualized as adding two columns to the right of Table 1, with headers such as "Developer Design" and "Teacher Design"). The resultant matrix can then provide a means for examining the interplay between the different decisions for a particular dimension.

In examining the designs of social infrastructure in the parallel-design matrix, one can use the dimensions of the Social Infrastructure Framework to identify and characterize the following:

- *Points of divergence.* Certain design dimensions may indicate divergences between developer and teacher designs. Again, the relationship is meant to be dialectical, not normative. What might explain such divergences? Are there specific classroom constraints that need to be taken into account? Are there aspects of the model that make direct implementation difficult? Examining the factors that explain such divergences may indicate various implementation conditions that need to be considered, and perhaps scaffolded, in order to support change.
- *Variations across iterations of teacher designs.* There may be dimensions along which teachers vary their designs across iterative cycles of implementation. What might explain why teachers varied design elements across time? Were particular challenges uncovered? Lessons learned? Transitions achieved? Design variations may support the generation of hypotheses regarding the affordances and constraints of particular implementation approaches.
- *Increased detail of dimensions.* Enacting a model in a classroom requires that teachers specify all of the dimensions of the Social Infrastructure Framework (either explicitly or implicitly through how the design is instantiated). In contrast, certain design elements may be specified in less detail by the developers of the model. Thus, teachers' designs may illuminate

TABLE 1
Summary of Social Infrastructure Framework Design Considerations

Dimension	*Design Considerations*	*Example Questions*
Cultural Beliefs	How learning and knowledge are conceptualized	How should the process of learning be viewed by teachers and students? What does it mean to "know"?
	How a student's social identity is understood	How should students view their purpose in the learning environment? How are students meant to view each other—as learning resources, as team members, as competitors? Are students meant to develop expertise and skills consistent with professionals in the "real world"?
	How a teacher's social identity is understood	How should teachers view their purpose in the learning environment? How are students meant to view the teacher? Are the teachers meant to be perceived as a fellow participant in the learning activities or as directors of the students' activities?
	How the purpose of the tool is viewed	How should the purpose of the tool be viewed by teachers and students? How are students meant to use the tool to carry out the learning objectives? How is the tool meant to fit into the overall workings of the classroom?
Practices	The planned learning activities	Should activity selection be left open to students, semi-structured, or tightly sequenced? Should all students carry out the same activities or should the activities differ according to the needs of particular students? Should remediation activities be provided if students have difficulties? Should learning the functionality of the tool be a separate activity or is the tool to be learned in the course of the broader set of activities?
	The associated participant structures of students	How are student groupings organized? In what ways are student interactions supported?
	The associated participant structures of teachers	Are the teachers meant to observe or intervene over the course of particular learning activities? What level of control do teachers take over the course of learning? How is teacher control balanced with helping students to learn how to direct their own learning experiences?
	The coordination of on-tool and off-tool activities	What is the relationship between on-tool and off-tool learning activities? Can off-tool and on-tool activities serve to reify concepts in different forms? Can off-tool and on-tool activities provide multiple modes for learning? Are there ways that offline activities can help students see the generality of what they are learning using the technology-based tool?

(*Continued*)

TABLE 1
(*Continued*)

Dimension	*Design Considerations*	*Example Questions*
Socio-Techno-Spatial Relations	Student–teacher–machine–physical space configurations	Are the computers located in the classroom or the computer lab? If students are using handhelds or wearable technologies, do they remain with the students, or are they kept in a central location under the control of the teacher? What is the formation of the computers-rows, circular arrangements, wherever there is space in the room? Is there space for students to put learning materials beside the machines as they work? Where and what are teachers doing while students work online?
	Student–teacher–cyberspace configurations	Do students work separately or collaboratively in cyberspace? How are student products organized in cyberspace—for example, are they grouped into categories, indexed alphabetically, or randomly arranged? Is online work visible and/or accessible to all? Are teachers meant to get online and use the tool themselves or to shape the online activities by working with students in the offline arena?
	Cyberspace–physical space relations	What are the tradeoffs between using data captured from the students' physical world as compared to other sources of data? Is it helpful to bring online work into offline forms? What are the affordances of the different means of displaying and interacting with student work?
Interaction with the "Outside World"	Bringing in knowledge from the outside	What sources of outside help might be useful? What is the best way to access such sources? What is needed to make the interaction successful? (e.g., Is training of outside resource people necessary?)
	Extending the audience for student work	Will the outside audience be active in responding to students' work or passive recipients? What types of supports are required?
	Collaborating with others outside of the classroom	What will be the common activities of the co-collaborators? How will their interactions be structured? Will the technology-based tool itself be used to facilitate the interactions?

Reprinted from Bielaczyc (2006, pp. 314–315).

> critical facets of the social infrastructure that are not fully detailed by the developers. The opportunity to understand factors impacting teachers' design specifications, the impact of specific design choices, and the insights of teachers may suggest refinements to the educational model itself.

Investigating each of these areas permits a systematic analysis of both design features and ways of supporting implementation of the educational model. Because the focus here is on understanding how teacher designs can help design researchers to construct implementation paths, the present article focuses on the first type of analysis, examining *points of divergence.* Such an approach can provide insight into possible transitional steps concerning how to reach the goal state of the model. The second and third analysis types primarily contribute to providing a deeper understanding and more detailed specification of the goal state itself. The second type, involving design variations across iterations, may also yield information about transitional steps if the iterations provide a trajectory.

CASE STUDY: KNOWLEDGE-BUILDING CLASSROOMS

One way to develop a deeper understanding of teachers' designs of social infrastructure and of the lessons that design researchers can learn in examining such designs is to focus on an example case. Here the Social Infrastructure Framework is used to analyze the design of classroom social structures by a particular team of teachers who worked over the course of several years to adopt the Knowledge Building Communities (KBC) model developed by Marlene Scardamalia, Carl Bereiter, and their colleagues (Bereiter, 2002; Scardamalia, 2001, 2002, 2004; Scardamalia & Bereiter, 1991, 1994).

The vision of *classrooms as knowledge-building communities* is for students to build collective knowledge with "fidelity to the ways work with ideas is carried out in the real world" (Scardamalia, 2002, p. 74). According to Scardamalia and Bereiter (2002),

> The basic premise of the knowledge building approach is that, although achievements may differ, the process of knowledge building is essentially the same across the trajectory running from early childhood to the most advanced levels of theorizing, invention, and design, and across the spectrum of knowledge creating organizations, within and beyond school. If learners are engaged in processes only suitable for school, then they are not engaged in knowledge building. (p. 1371)

Advancing the frontiers of knowledge is the central aim of the community. Students are meant to develop the epistemic agency to identify problems of understanding, create theories, carry out research and investigations in order to

refine their theories over time, revise their problems and strategies, and share and monitor the progress of the community toward its goals.

I chose to look at the KBC model for several reasons. It is a well-known model in the learning sciences and computer-supported collaborative learning communities (e.g., Koschmann, Hall, & Miyake, 2002; Sawyer, 2006). There has developed a strong development infrastructure, including an annual Knowledge Forum Summer Institute in which developers, teachers, and other local adaptors work together to deepen their understanding of the model and the related educational goals. The KBC model also has wide applicability and is currently being used in K–12 classrooms and university settings, as well as in health care, community, and business contexts, across North America, Asia, and Europe (e.g., Chan, 2011; Hakkarainen, 2009; Lax, Scardamalia, Watt-Watson, Hunter, & Bereiter, 2010; Oshima, Murayama, & Takenaka, 2004; van Aalst & Truong, 2011; Zhang, Hong, Scardamalia, Teo, & Morley, 2011). Furthermore, Knowledge Forum,[1] the software that embodies and supports the model, has a long history in research on cognition and educational technology (Scardamalia, 2004; Scardamalia & Bereiter, 1994). The software was first prototyped in 1983, the Computer-Supported Intentional Learning Environments (CSILE) software was developed in 1985, and in 1995 it was reengineered by Learning in Motion as a commercial product called Knowledge Forum.[2] Not only has the software evolved but so too has the vision for its use (e.g., Bereiter, 2002; Bereiter & Scardamalia, 1993, 2003; Scardamalia, 2002).

Given this history, it was assumed that the design work would be quite rich—for both the developers and the many teachers who have worked with Knowledge Forum over the years. However, neither the developers nor the teachers had been explicitly guided by the Social Infrastructure Framework. What can be learned in using it as an analytic lens? In the case study, the Social Infrastructure Framework is used to reverse-engineer the developers' and teachers' design decisions concerning social infrastructure in order to construct a parallel-design matrix. Examining this particular case through the lens of the Social Infrastructure Framework shows the power of making such design decisions explicit.

The Whitman Team

I became interested in the Whitman Team after hearing about them at one of the annual Knowledge Forum Summer Institutes. Many researchers and teachers at

[1] It should be noted that the KBC model and the name of its associated software, Knowledge Forum, have become quite synonymous in educational circles over the years. It is not uncommon for people to refer to classrooms that have adopted the model as "Knowledge Forum classrooms," and even the name of the annual conference focused on advancing understanding of the educational model is the Knowledge Forum Summer Institute. The teachers in the case study presented here also used the name for the model and the name for the software interchangeably.

[2] See http://www.learninginmotion.com.

the Institute referred to the four Whitman teachers as having developed some of the "best practices" around creating a classroom learning community with Knowledge Forum. Two of the teachers on the Whitman Team had been teaching for more than 25 years and were excited by their work because they felt that the student learning going on in their classrooms now was the best learning that they had experienced during their careers. The Whitman teachers' involvement in the knowledge-building work had originated in a talk given by Scardamalia and Bereiter that was attended by the head of their school district. The district head then recruited this teacher team, and the teachers began attending the yearly Knowledge Forum Summer Institutes. The teachers had sustained their use of Knowledge Forum for more than 8 years, with very little external support. One of the original team members retired after the first 4 years and was replaced; three of the original team members participated continuously for 8 years. Because these teachers were not tightly coupled to the developers, the context provided an opportunity to look at the types of social structures developed by the teachers themselves.

The teachers worked at Whitman Middle School, a small suburban school in the midwestern United States serving approximately 600 students in Grades 6 through 8. During the period of my research, the Whitman Team consisted of four teachers with classrooms of roughly 25 students each. The teachers and students stayed together for two school years, starting in sixth grade when the students first came to Whitman Middle School and continuing through seventh grade. Knowledge Forum was a part of the learning environment throughout the entire 2 years. There were three research units across each year. For example, the research units in seventh grade were as follows:

- *Fall term: Global Understanding.* Student investigations focused on countries from around the world.
- *Winter term: World Religions.* Student investigations focused on six major world religions: Buddhism, Christianity, Hinduism, Islam, Judaism, and Taoism.
- *Spring term: Astronomy/History of Technology.* Student investigations focused on either astronomy or the history of technology. The students divided themselves quite evenly between the two.

The teachers gave each unit the same basic structure: (a) carrying out sustained investigations for 8–10 weeks, (b) focusing on problems within the research topic, and (c) working individually and in small groups toward building a shared understanding.

Each teacher on the team specialized in one subject matter area: math, science, social studies, or personal development. Students started the day in their respective homerooms, where all of the teachers taught language arts. Beginning in Period

2 and continuing for subsequent periods, each teacher taught his or her specialized subject matter. The students moved from one classroom to the next, and hence one subject matter to another, over the course of the school day.

However, the Knowledge Forum investigations were independent of these divisions. The community that the Whitman Team worked to build spanned across all four classes—students worked on the same research unit in a single database containing the work of approximately 100 students. The teachers developed a scheduling method that would allow all children to work on their Knowledge Forum investigations for roughly an hour a day, for 5 days a week. Each day, on a rotating basis, one teacher would host the "Knowledge Forum class." A given teacher hosted Knowledge Forum every fourth day for four consecutive 50-min periods. When students came to the designated class, they spent the period working on their Knowledge Forum research unit rather than the usual subject matter curriculum.

An example of the schedule for students in Mr. W's homeroom is provided in Figure 2. Each day began with language arts in the students' homeroom classroom with Mr. W. This was followed by either mathematics or Knowledge Forum, depending on whether it was Mr. W's turn to host the Knowledge Forum class (in the schedule shown, Mr. W's day falls on Thursday for this particular week). This group of students then moved to Mr. J's classroom, then lunch, then Ms. S's classroom, and then finally to Ms. K's classroom. As students moved to a new classroom, the focus for the given period depended on whether the teacher was

	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Period 1	Language Arts Mr.W	Language Arts Mr.W	Language Arts Mr.W	Language Arts Mr.W	Language Arts Mr.W
Period 2	Math Mr.W	Math Mr.W	Math Mr.W	Knowledge Forum Mr. W	Math Mr.W
Period 3	Knowledge Forum Mr.J	Science Mr.J	Science Mr.J	Science Mr.J	Knowledge Forum Mr.J
Period 4	Lunch/ Electives	Lunch/ Electives	Lunch/ Electives	Lunch/ Electives	Lunch/ Electives
Period 5	Social Studies Ms.S	Knowledge Forum Ms.S	Social Studies Ms.S	Social Studies Ms.S	Social Studies Ms.S
Period 6	Personal Development Ms.K	Personal Development Ms.K	Knowledge Forum Ms.K	Personal Development Ms.K	Personal Development Ms.K

FIGURE 2 Schedule for students in Mr. W's homeroom.

hosting the Knowledge Forum class for that particular day. The other three groups of students in the Whitman Team had similar schedules, but they each started their day with their own homeroom teacher and then rotated into the other three teachers' classrooms during different periods. For the schedule shown, Mr. J will host the Knowledge Forum class for all four groups of students across Periods 2, 3, 5, and 6 on both Monday and Friday; Ms. S will do so on Tuesday; Ms. K on Wednesday; and Mr. W on Thursday. In the following week, the cycle will begin again, with Ms. S as the Monday teacher.

Data Sources and Analysis

As stated previously, neither the developers of the KBC model (hereafter, the KBC developers) nor the Whitman teachers were explicitly guided by the Social Infrastructure Framework. The analysis involves examining the work of both the developers and the teachers for design decisions concerning classroom social structures in order to construct the 14 × 2 parallel-design matrix. One of the largest challenges in collecting the data for constructing the parallel-design matrix is that much of the developers' design descriptions are found in publications written for academic audiences, and the teachers' design knowledge tends to be tacit. For this reason, it is critical to go beyond the literature and basic teacher self-reports in order to interrogate a variety of sources of design knowledge. Iterations of data triangulation and member checking with both developers and teachers are also critical. The data sources used for the knowledge-building communities case study are detailed here and further elaborated throughout the article. It should also be noted that I have developed my own fluency with elements of the design over years of work with the KBC model, including directing projects focusing on teacher and student reflections on creating classroom knowledge-building communities (e.g., Bielaczyc, 2001; Bielaczyc & Blake, 2006; Bielaczyc & Collins, 2006b; Bielaczyc & Ow, 2007; Caswell & Bielaczyc, 2002).

The developer data used in the case study were drawn from the Knowledge Forum literature, participation in annual Knowledge Forum Summer Institutes, my postdoctoral affiliation with the Knowledge Forum project, and conversations with the developers about this article. The data from the Whitman Team classrooms were collected over the course of one and a half academic years. Beginning in the spring of the sixth-grade year and continuing until the end of the seventh grade, I made classroom visits roughly every 6 weeks for a period of 5 days. Data collection included the use of classroom observations, student and teacher interviews, surveys and written data, along with online data from the Knowledge Forum databases.

The KBC developers' specifications of the KBC model were mapped onto the dimensions of the Social Infrastructure Framework based on the literature,

demo videos, and websites[3] of the development team. Both the Cultural Beliefs Dimension and most areas of the Socio-Techno-Spatial Relations Dimension have become highly elaborated over 25 years of developing the model and software embodying the model. Specifications can be found in publications (e.g., Bereiter, 2002; Bereiter & Scardamalia, 1993, 2003; Scardamalia, 2001, 2002, 2003a, 2003b, 2004; Scardamalia & Bereiter, 1991, 1994, 1996, 2007, 2008), in examples of use detailed in demo videos, and in classroom cases on the websites. Many aspects of the Practices Dimension have been specified through a set of 12 major design principles (see Scardamalia, 2002). Furthermore, although there are "no set patterns for CSILE use" (Scardamalia & Bereiter, 1996, p. 155), the developers have put forward a fundamental structure for classroom practices: (a) Students engage in a sustained investigation of topics in depth, usually over a period of months; (b) inquiry focuses on problems rather than categories of knowledge (e.g., how does the heart work rather than the heart); and (c) each student engages in inquiry of importance to him or her while working to advance the collective understanding (Scardamalia & Bereiter, 1996). The KBC developers have elaborated various design elements related to the Interaction With the "Outside World" Dimension through their work on *virtual visits*—a means of connecting classroom-based knowledge-building communities with specific visitors or with wider communities of persons building knowledge in similar areas of inquiry (Scardamalia, 2003b).

In order to construct the design matrix for the Whitman Team, I drew specifically on teacher data collected from four Saturday reflection meetings held with the Whitman teachers over the course of the seventh-grade year and field notes taken during classroom observations and while I was attending the teachers' planning meetings during school visits. Along with member checking of the design elements, subsequent conference presentations and conversations with the teachers also served as checks on the design dimensions.

I specifically designed the Saturday reflection meetings to elicit teachers' design knowledge regarding classroom implementation of the KBC model. Richardson and Placier (2001) discussed how teacher engagement in reforms "often leads to change in tacit knowledge that becomes expressed only through reflection, a process that is enhanced through dialogue" (p. 908). The sessions involved the four teachers reflecting on and discussing both demo videos of the KBC developers and videos of their own students reflecting on the knowledge-building processes (the videos were filmed during my interviews with the Whitman Team students and included a spectrum of experiences, questions, and challenges). Teachers' discussions spanned the implementation of the model in their classrooms; their interactions with the developers and other teachers in

[3] Specifically, http://ikit.org/ and http://www.knowledgeforum.com/.

the KBC international community (e.g., through participation in the Summer Institute); and their personal trajectories as teachers, including their pedagogical philosophies.

The developer and teacher quotes used in this article are based on making multiple passes through the data sources for various dimensions of the Social Infrastructure Framework, iteratively determining emergent themes supported through data triangulation based on additional data sources and member checking. For example, the Saturday reflection meetings resulted in fully transcribed interactions over approximately 12 hr, which were coded into categories corresponding to the design dimensions. Additional detail was provided through classroom observational data and notes from teacher planning meetings. The data collection methodology merits further refinement in future work; here I focus on an argument for the plausibility of the parallel-design matrix analysis technique and its value to design researchers.

LEARNING FROM THE WHITMAN TEAM DESIGNS

The central purpose of this case study is to provide examples of how investigating teacher design decisions can inform design research focused on practical implementation. I am interested in the ways in which the Whitman teachers designed social infrastructure for supporting a classroom knowledge-building community. It should be noted that the developers and teachers have made numerous design decisions regarding classroom social structures. The present case study is illustrative, not exhaustive. Here I focus on lessons learned through constructing a parallel-design matrix and examining elements in the matrix for points of divergence between the design specifications of the KBC developers and those of the Whitman teachers.

In the case of the Whitman Team analysis, the design divergences that were identified occurred along two subdimensions: conceptualization of student social identity and student–teacher–cyberspace configurations. The divergence in the *conceptualization of student social identity* concerned teachers seeming to place greater emphasis on individual investigations and person-to-person relationships as compared to the developers' focus on the collective and person-to-enterprise relationships (i.e., working toward the common enterprise of advancing the community's understanding). The divergence in *student–teacher–cyberspace configurations* concerned differences between the ways in which teachers and developers approached the content and focus of Knowledge Forum notes. In order to better understand the implications of the divergence analysis for the construction of potential implementation paths, I present analyses of the work of the KBC developers and the Whitman teachers.

Divergences Between the KBC Developers' and Whitman Team's Conceptualizations of Student Social Identity

The Cultural Beliefs Dimension concerns the type of classroom culture that is cultivated. Within this dimension, the conceptualization of student social identity refers to how students view themselves as learners and how they perceive the role that other students in the class (and others in their social network) play with regard to their own learning.

The KBC developers' conceptualization of student social identity. The KBC developers' perspective on students' social identity centers on two key ideas. The first concerns *epistemic agency,* which involves "turning over to the students the parts of the educational process that are normally reserved for the teacher" (Scardamalia & Bereiter, 2008, p. 5). The second concerns *collective cognitive responsibility,* which involves students taking on the social responsibility of working to advance not only their own knowledge but also that of the entire classroom community—"the ability and willingness to take on responsibility for the collective solution of knowledge problems" (Scardamalia, 2002, p. 70). The idea is to go beyond fidelity between student work and the real world of work at the *individual level* (e.g., casting students as physicists or historians) to the *community level* (e.g., the classroom working in similar ways to the community of scientists or historians; Scardamalia & Bereiter, 1994).

The following questions relate to the developers' conceptualizations of students' social identity in knowledge-building classrooms (from Scardamalia, 2003a, p. 14):

- Are students empowered to take responsibility at the highest levels of knowledge work—to establish goals beyond what others set for them?
- Do students take pride in the knowledge advances of the whole community, share responsibility for what is accomplished, and value others' contributions as well as their own?
- Do students view their work as an extension of the way ideas evolve in out-of-school contexts?
- Do students see their own minds and the world around them as a powerful source of improvable ideas, or is their role confined to asking questions, to which others have answers?

The Whitman Team's conceptualization of student social identity. The Whitman teachers described their main educational objective as creating a "learning club" in which members learn how to learn. Becoming a member of the learning club was seen as involving two complementary areas of student growth: development of (a) confidence in oneself as a learner who can advance one's own understanding and who has something to contribute to the community's

understanding; and (b) a sense of being part of a team, in which others are valued as learning resources, allowing one to go beyond what is possible alone.

One of the teachers emphasized that he wanted learners to experience the joy of discovering "Gee, I didn't know I could do that." He viewed such experiences as critical in shifting students' perspectives that "going to school and learning is not just something being done to them" toward realizing "I have something to contribute":

> Bielaczyc: Why is that important? . . . That they get that sense of themselves?
> Mr. W: Well, I think it makes you a more productive person. What we want in this world are people who are confident in their ability to put together ideas and to contribute, and if you are always going through life thinking that somebody is going to be doing this for you and raising the critical questions, we're not going to have a productive society. But once you begin to realize that I have something to contribute, that I have contributed, that I can learn, that I can see what the issues are, along with someone else, that I don't just have to wait for somebody to tell me, I think we're going to be better off.

Hence, a student's social identity involved a sense of autonomy and confidence in one's ability to learn and to make valuable contributions:

> Kids see themselves as learners. And when you ask them to reflect, it's really celebrate, not reflect, but any new learning that they come, any learning that they come to school with is being celebrated because they have to realize that they are a learner. And that's the powerful thing about going to school. You do school because this is what I know, and now I'm pushing myself more forward to learn more and to become reflective and think about learning itself. Because I think kids don't see themselves as really learners, and I think that's powerfully important for them to understand that they have a lot of power in learning.

The Whitman teachers often talked about "celebrating" students' efforts in pushing themselves "forward to learn more and to become reflective and think about learning itself." It was important for them that their students come to understand the power that they themselves can have if they understand how to learn and "see themselves as learners."

Furthermore, the teachers felt that one's identity needs to also extend beyond the self, to feel a part of a larger whole:

> There has to be a very strong feeling of collaborative learning that exists and of the whole idea of team. That has to be fostered over and over and over again if anything like that is going to work, that this person sitting next to me is an important part of my learning . . . There has to be a measure, a great measure of respect that each one of the kids has for the other kids on the team. They have to look at each other as

> partners. They have to see each other as researchers, and they have to respect what each of them has to say and what each of them has to contribute to whatever the learning happens to be.

It was also important that one's social identity be relevant beyond the school setting:

> I suppose it's the word *community.* It seems like wherever you go and whatever job you do and whatever discipline it may be in, you have to rely on other people to build the communities just like on our team.

The teachers felt that in working as a knowledge-building community, their students gained a sense of pride and purpose. That students were given a voice and were heard not only by their peers and teachers but by other adults as well:

> I mean, it was just like you had pinned a badge on them . . . It had been somebody referred to something they said or somebody picked up on their idea, or somebody asked them a question . . . But it's just like your inside is ballooning when you become aware of something. It's a wonderful feeling. And there are kids in our classrooms, and they can go through their entire school and indeed their entire life and they've never been blown up by learning. And it happens more here and for more kids because there's more opportunity to be heard. Other teachers listening. There are other adults who are listening.

It was important to the Whitman teachers that students see themselves as active, contributing participants in their classroom community. This involved feeling part of a team, respecting the ideas of others, and listening to others as well as being listened to. The hope was to create the confidence and ability to communicate and collaborate not only in the classroom but also as they go out and become workers in the world beyond school.

Discussion of conceptualization of student social identity. The Whitman teachers centered their conceptualization of student social identity on being part of a "learning club" in which students take responsibility for improving their ideas and the ideas of other members. The goal was for students to see themselves and others as powerful contributors to the world of ideas. The teachers also emphasized that this approach to knowledge and learning is not confined to the school context but is about making the school context consistent with knowledge work in the real world. These conceptualizations were geared toward helping students to develop metaknowledge: This is how people work with ideas—not just in school, but also in life.

Such a conceptualization of social identity appears to be consistent with the conceptualizations put forward by the KBC developers. On the surface, both

the KBC developers and the Whitman teachers emphasize that students should understand their social identity as being part of something greater than themselves. In addition, both the developers and the teachers want student work with knowledge to be similar to knowledge work in the world outside of the classroom walls. However, a closer analysis reveals that the central notion for the KBC developers is that the social identity is a *person-to-collective enterprise relationship:* We are here to build a collective understanding, to advance what we know as a community. Students are meant to see themselves and one another as working toward this common enterprise. For the Whitman teachers, a student's social identity was expressed as a *person-to-person relationship:* We are here to help each other to learn. The emphasis was on students viewing themselves and each other as resources for their individual investigations. Furthermore, the Whitman Team's conceptualizations placed an emphasis on individual knowledge rather than on collective knowledge. Cultivating a student sense of an entity of *collective knowledge* was not as clearly emphasized as the entity of *one's own knowledge.*

Although the ways in which knowledge, learning, and student social identity are conceptualized by the Whitman Team and the KBC developers may seem more closely aligned than not, it is instructive to investigate the points of divergence and to generate hypotheses about why inconsistencies might exist. There are several possible (and not necessarily mutually exclusive) explanations for divergence: (a) *clarity:* this particular aspect of the educational model may not have been well understood by the teachers, (b) *disagreement:* the teachers may have disagreed with this particular aspect, and/or (c) *local constraints and needs:* the teachers were faced with constraints or needs in their local context that made this particular aspect challenging.

In this case, one explanation might be that the Whitman teachers did not have a good grasp of communal knowledge as an entity and what it means to be involved in the enterprise of advancing collective understanding. In fact, in one of my group interview sessions with the teachers, I raised the distinction between "helping others' individual inquiry" and "building a communal understanding." In discussing this distinction, the four teachers agreed that the concept of "communal knowledge" was difficult to fully grasp, even after 8 years:

> And I think as long as we have worked with CSILE and Knowledge Forum, the first is fairly easy to comprehend and fairly easy to see students doing this readily. You know, how does that student help that student. And for years we've seen that happen. But this whole understanding of the communal database is so nebulous and so large that I think it's what I feel is a big challenge still in seeing how that happens and how we can make attempts to facilitate that. It's a biggie.

The hypothesis that the Whitman teachers might have experienced difficulty in developing a good feel for the meaning of "communal knowledge" or "collective

understanding" is not unreasonable according to the literature on group processes in schools (e.g., Senge et al., 2000; Webb & Palincsar, 1996) and team learning and organizational learning in the workplace (e.g., Argyris & Schon, 1996; Brooks, 1994; Donnellon, 1995; Hackman, 1990; Senge, 1990). For example, Brooks (1994) pointed out that

> the shift to working in teams in many U.S. work organizations represents not just a structural change in how work is done, but a significant historical and cultural shift that affects the way many individuals identify themselves and attempt to establish their social worth. (p. 231)

Thus, the Whitman teachers' struggle with the concept could be representative of a difficulty faced by members in the wider society.

However, this hypothesis does not seem to be well supported. The teachers were able to articulate definitions of communal knowledge and understanding that were consistent with the types of definitions expressed by the KBC developers. Furthermore, the teachers often described themselves as working as a knowledge-building community among four teachers locally and as part of a larger community globally. They worked together to discuss and build a shared understanding of the KBC literature and held daily design meetings in which they worked toward a common design. They also shared these communal understandings as part of professional development sessions that they would lead with other teachers at the Knowledge Forum Summer Institute.

Another explanation for why points of divergence might exist between the ways in which knowledge and student social identity were conceptualized by the Whitman Team and the KBC developers may be that the Whitman teachers disagreed with the importance of fostering a *person-to-collective enterprise relationship.* However, nothing said by the teachers over the course of the years seems to indicate such a stance.

The local constraints and needs of the Whitman Team classrooms provide explanations for the divergence. The teachers found that working with such a large number of students posed challenges to keeping track of "what we know" as a collective. As one of the teachers described,

> Because we work with 100 kids, this is very difficult for us. If I was teaching fifth grade and I had my homeroom and I worked with four or five groups every day, I think that would be a lot easier to keep your finger on.

Working with 100 students and the large number of entries in the database made it very difficult to foster communal discourse and identity.

In addition, the Whitman teachers spoke of how the classroom culture that they were attempting to create was quite a change for students who had already come

through 6 years of traditional schooling. The Whitman teachers also felt that social pressures against working together may be stronger during puberty:

> They have to see each other as researchers, and they have to respect what each of them has to say and what each of them has to contribute to whatever the learning happens to be. And having said that, if you reflect on that, that is a big order when you're putting it into the environment of a middle school where kids have an awful time respecting each other, feeling as if they belong together, where you have cliques and all that kind of stuff. . . . You are working in, sometimes in an environment that does not lend itself to that kind of behavior. If you have a very small group, yes, perhaps that might work. But if you don't have a small group, if you're working with large, collective groups of people, you really have to work hard at that.

The teachers felt that the students found it difficult to "see each other as researchers" and to respect what others have to contribute to the learning process. This posed problems for engaging in the types of social interactions that they need to be comfortable with in a KBC classroom:

> It's OK to ask for help. That is very hard for kids to do. It's very hard for them to admit that there might be something that they don't know. If it's OK to ask questions then obviously some of the things you're asking questions about are things that you don't know. But that is not often admitted. Kids go to school for years and find a place in the room where they can shrink up and not be seen and not be heard but as far as they're convinced it is *not* OK to ask questions. That is a very scary thing to do.

Thus, social discomfort, and even disengagement, might be expected from immersing the students straight away into having peers publicly ask questions about their knowledge work and critiquing and working with one another's ideas. Because the Whitman Team's efforts toward building *person-to-person relationships* were focused on ways to help students to build confidence in themselves as learners and come to view one another as resources for learning, such an approach may have helped them to address this local need.

The goal in the present section is to examine the design divergences between the Whitman Team and the KBC developers across a particular dimension and to seek explanations for why teachers may have implemented these particular design strategies. After a similar analysis of the design divergences introduced next, the implications for the creation of implementation paths is described in detail.

Divergences Between the KBC Developers' and Whitman Team's Student–Teacher–Cyberspace Configurations

The Socio-Techno-Spatial Dimension concerns how the physical space and cyberspace components of the learning environment are organized. The

parallel-design matrix revealed divergences between the KBC developers and Whitman Team within the subdimension of student–teacher–cyberspace configurations concerning the presentation and organization of students' online work. Specifically, the divergences concerned the focus and content of the Knowledge Forum notes.

One such divergence was pointed out by the Whitman teachers themselves during one of the Saturday reflection sessions. In the session, the Whitman teachers watched a demo video created by the KBC developers. The demo video introduced the central ideas of knowledge-building communities, results of research, and the features of Knowledge Forum along with several classroom examples of Knowledge Forum use. After watching the video, one of the teachers made the following observation:

> Well, I think one of the most obvious things is that the notes as they were presented on that video are fairly specific in their intention. The intention of a note in that demonstration is more of a single purpose, whereas we have more of a dialogue. And many, many ideas are shared on one note. So that's [noise obscures] difference.

An overview of the designs of the KBC developers and the Whitman Team with regard to the purpose and content of Knowledge Forum notes is presented here, followed by a discussion of the design divergences.

The KBC developers' student–teacher–cyberspace configurations. Knowledge Forum is specifically designed to support creative knowledge work. According to Scardamalia and Bereiter (2008),

> The heart of CSILE/Knowledge Forum is a multimedia community knowledge space. In the form of notes, participants contribute theories, working models, plans, evidence, reference material, and so forth to this shared space. The software provides knowledge building supports both in the creation of these notes and in the ways they are displayed, linked, and made objects of further work. Revisions, elaborations, and reorganizations over time provide a record of group advances, like the accumulation of research advances in a scholarly discipline. (p. 5)

In brief, as students work on investigations, they enter their ideas and research findings into the Knowledge Forum database. Contributions can take many forms, including (a) *notes,* in which students state problems, advance initial theories, summarize what needs to be understood in order to progress on a problem or to improve their theories, provide a drawing or diagram, and so on; (b) *views,* which is a window that allows graphical organizations of related notes; (c) *build-ons,* which allow connections to be made among notes; and (d) *"rise-above" notes,* which can be used to synthesize notes in the knowledge base. Any of these kinds of contributions can be jointly authored. The environment supports students in

constructing their notes through features such as theory-building scaffolds (e.g., "My Theory," "I Need to Understand"). Students can read through the knowledge base, adding text, graphics, questions, links to other notes, and comments on each other's work (for more detail, refer to Scardamalia, 2004).

For the present analysis, it is important to first explain two particular design affordances in the Knowledge Forum software. First, when the KBC developers moved from CSILE to Knowledge Forum, one concern was to break from the problem of ideas becoming fixed in chronological order. CSILE had a particular feature, the *discussion note,* that supported communal discourse among multiple students within a single note. When students contributed to a discussion note, each new entry was added into the note in sequential order, even if the new entry referred back to an idea introduced much earlier in the sequence (see Figure 3). Because the entries were fixed in sequential order, this resulted in a "challenge to figure out what someone is talking about, because the message refers back to an unidentified message some distance back in the queue" (Scardamalia & Bereiter, 2008, p. 7). In contrast, in Knowledge Forum the notes and build-ons permit students to enter ideas in the database in ways that provide much greater flexibility for showing interconnections.

To illustrate, refer to the examples shown in Figures 3–6. Figure 3 shows a sample CSILE discussion note (from Hewitt, 2004). In Knowledge Forum, the same discussion could be recreated with each entry of the discussion note entered into the knowledge base as its own note. This is shown in Figure 4, using the same first four entries of the CSILE discussion note in Figure 3. Because the build-on feature allows each separate note to be built on (advanced), the connections among entries can be based on the interconnections users choose to create rather than fixed in chronological order (see Figure 5). Knowledge Forum also has a Reader feature that allows multiple notes to be collected in a single window and allows different ways of sequencing notes. The Knowledge Forum Reader window shown in Figure 6 reads quite similarly to the original CSILE discussion note, but the notes need not be read in this order (the options are shown in the pull-down menu *Sort by: As Added, Title, Author,* etc.).

The second feature relevant for the present analysis is the view. In order to support the concept that ideas can be viewed from multiple perspectives, the same note can appear in multiple views. Any edits made to the content of the note become updated automatically in all of the views in which the note appears. As the example in Figure 7 shows, if students have created notes about various dinosaurs, the same note can be used as part of different conceptualizations (based on an example drawn from Scardamalia & Bereiter, 2006). In the Dino Types view, the notes are used to create a classification of dinosaurs. In the Geological Time view, the notes are grouped according to geological periods. In the Dinosaur Food Chain view, the notes are used to show food chain relationships and to specify dinosaurs as plant eaters or meat eaters.

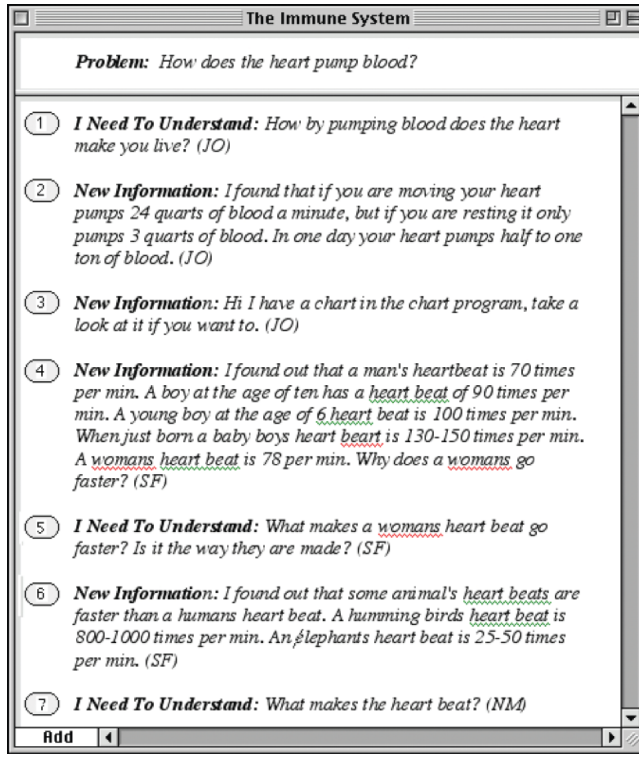

FIGURE 3 Computer-Supported Intentional Learning Environments (CSILE) discussion note with entries from three students (JO, SF, and NM) (color figure available online).

The point of understanding these two features of Knowledge Forum is to highlight that the note is intended to provide flexibility in working with ideas. For the KBC developers, the notes are meant to serve as one of the central ways in which students can create "conceptual artifacts" in which knowledge can be treated as objects or tools for members of the community to work with. Scardamalia and Bereiter (2002) underscored the importance of treating ideas

> as real things, as objects of inquiry and improvement in their own right . . . This means not only preserving them but making them available to the whole community in a form that allows them to be discussed, interconnected, revised, and superseded. (p. 3)

Thus, for the developers, the notes that lend themselves best to such desired uses are notes focused on specific knowledge objects such as theories, questions, problem formulations, and research findings. In other words, although there are no

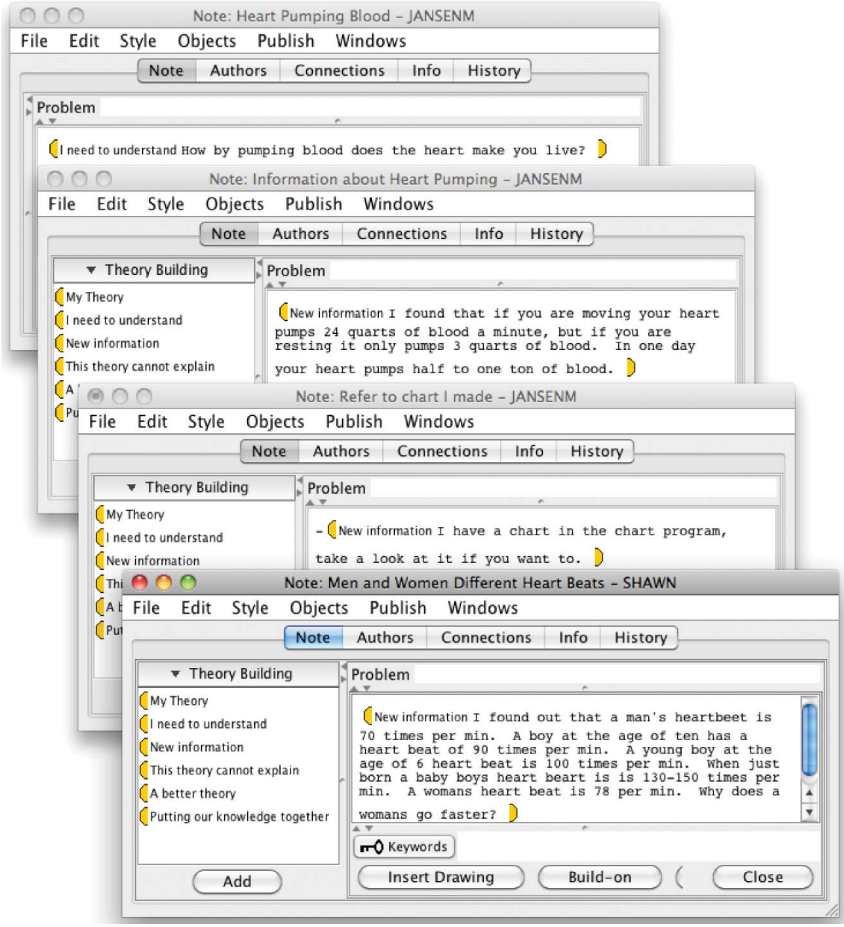

FIGURE 4 Four separate notes in Knowledge Forum (color figure available online).

software constraints on how many knowledge objects a note can contain, creating notes focused on a single knowledge object (a) avoids fixing multiple knowledge objects in sequential order within a note and (b) permits the same knowledge object to be represented from different perspectives via the use of the same note in different views (J. Hewitt, personal communication, November 22, 2010).

The Whitman Team's student–teacher–cyberspace configurations. In the Whitman Team classrooms, the teachers had students create a main research note for each unit. These notes did not focus on a single knowledge object. Instead,

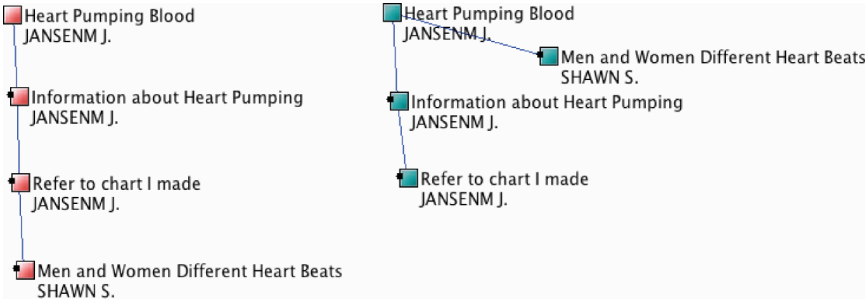

FIGURE 5 Two possible note sequences from Figure 4 on view (color figure available online).

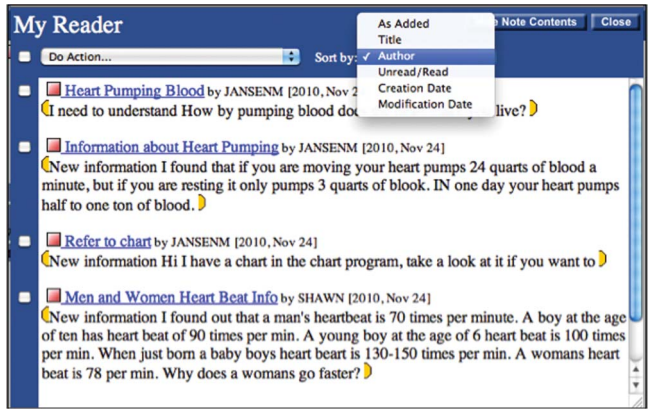

FIGURE 6 Notes from Figure 4 in the Reader (color figure available online).

these notes contained multiple knowledge objects that followed a particular organizational structure that the Whitman Team called the "learning cycle." The basic structure of the learning cycle is depicted in Figure 8. The teachers viewed the learning cycle as providing a process for supporting students in building knowledge and a means for visualizing the "journey of their learning" over time. Using the learning cycle to structure students' notes also helped communal sharing by providing a common format that helped students to quickly orient themselves in one another's notes.

The Whitman Team also continued to create "discussion notes" in Knowledge Forum, even though the specific feature was no longer part of Knowledge Forum. This required some special arrangements, as database software needs to be specifically designed to support multiple users accessing the same note (to avoid

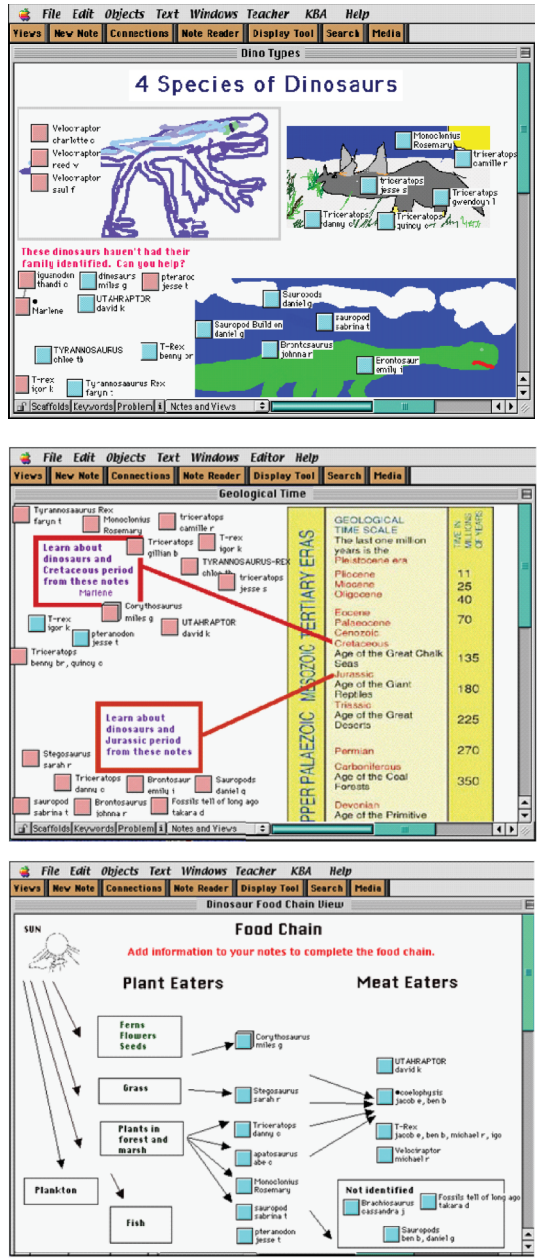

FIGURE 7 An example of different perspectives (views) on the same notes (color figure available online).

Problem: express problem question to guide my research
WITIK: describe "What I Think I Know" about my area of inquiry

- **INTU**: determine what "I Need To Understand"
- **Theory**: propose Theories that provide answers to my INTU's
- **Plan**: make a list of the steps I need to find materials, experiences, and people that will help me gain new understanding in relation to my questions
- **New Learnings**: share understandings I have gained through my research

Then begin the cycle anew

- **INTU**: determine what new questions arise
- **Theory**
- **Plan**
- **New Learnings**

Then begin the cycle anew

- **INTU**: determine what new questions arise
- **Theory**
- **Plan**
- **New Learnings** (continue to cycle…)

Complete the entire process by reflecting back across all of the cycles

- **Reflecting on the "Journey of My Learning"**: what have I learned during the course of my inquiry?

FIGURE 8 The basic structure of the Whitman Team's learning cycle.

overwriting in the database). The CSILE discussion note feature was specifically designed to support multiple access. Knowledge Forum permits multiply authored notes, but the default assumption is that the knowledge object in the note is created by multiple persons, not that multiple persons will be accessing the note and making entries separately. Thus, in order to allow multiply authored notes to function as forums for discussions, the Whitman Team implemented an offline system to complement Knowledge Forum. Each multiply authored note created by students was given a corresponding physical marker that hung on a board accessible to all students. If students wanted to make entries to such a note, then they needed to possess the marker for that note. In this way, the Whitman Team was able to essentially replicate the CSILE discussion note feature in Knowledge Forum.

The final point regarding the Whitman Team's approach to using the cyberspace tools of the learning environment concerns *rise-above notes*. Although the Whitman teachers were aware that Knowledge Forum also includes a feature called the rise-above note, they never introduced this note type to their students. The teachers described how they liked the idea of the rise-above feature pushing students to "a new level of understanding" but found the functionality of the feature to be confusing and "we just didn't understand what it was." Because of this lack of understanding, this feature was not used.

Discussion of student–teacher–cyberspace configurations. Although the KBC developers do not specifically promote the learning cycle as the organizational structure for students to follow, the default scaffolds in Knowledge Forum bear a resemblance to the steps of the learning cycle. In Knowledge Forum the default scaffolds for theory building are *My Theory, I need to understand, New*

information, This theory cannot explain, A better theory, and *Putting our knowledge together.* In fact, the Whitman teachers talked about how they derived the learning cycle from meetings with the KBC developers in which the scaffolds were discussed (as part of CSILE):

> I think at some of those early meetings we went to when CSILE was in external research [inaudible] we went down to St. Louis, our very first exposure to this. And people were talking about the INTUs [I need to understands] and then, I, I need to understands, so the question then leads to theories and to new learning. So, I think it was sort of laid out for us that way, that, you know, the structure of the, they weren't called scaffolds necessarily then. I mean, they weren't in there as scaffolds, but the INTU, very early on, I mean, we just knew that was the, there's certain things that kids need to understand. And as we started our kids on it, that was something that we had to teach and that your questions lead to theories, and theories lead to new learning, and then you revise your theories and that it's not cyclical in that it's lock-stepped. You know, the cycle can reverse and then go on further or go back and come up with another theory. So, I think that part of just, that Marlene and Carl [Marlene Scardamalia and Carl Bereiter] were working on, that that would go on the note and you would label your note.

Furthermore, the teachers never presented the learning cycle as a strict procedure to be followed ("it's not cyclical in that it's lock-stepped"). Thus, the divergence was not in providing a supportive structure for progressive idea refinement per se but rather in whether the progressive refinement was to be carried out using a series of notes and build-ons in the space of Knowledge Forum (the KBC developers' approach) or within a single note (the Whitman teachers' approach).

Focusing on individually authored notes that contain entire learning cycles results in a further notable difference between the design approaches of the Whitman teachers and the KBC developers. Such notes put the responsibility for carrying out the progressive improvement of ideas with a single researcher. Other students could contribute their ideas through build-ons, but in the Whitman Team classrooms the learning cycle was intended primarily as an individual construction. However, Scardamalia and Bereiter (1994) contrasted the KBC model and other contemporary models of learning that seek fidelity between student work and the real world of work by pointing out that these other models tend to cast students in the role of physicists, historians, and the like at the level of the individual. Instead, they proposed,

> More significant implications follow if the question is reformulated at the level of the group rather than the individual. Can a classroom function as a knowledge building community similar to the knowledge building communities that make up the learned disciplines? (p. 270)

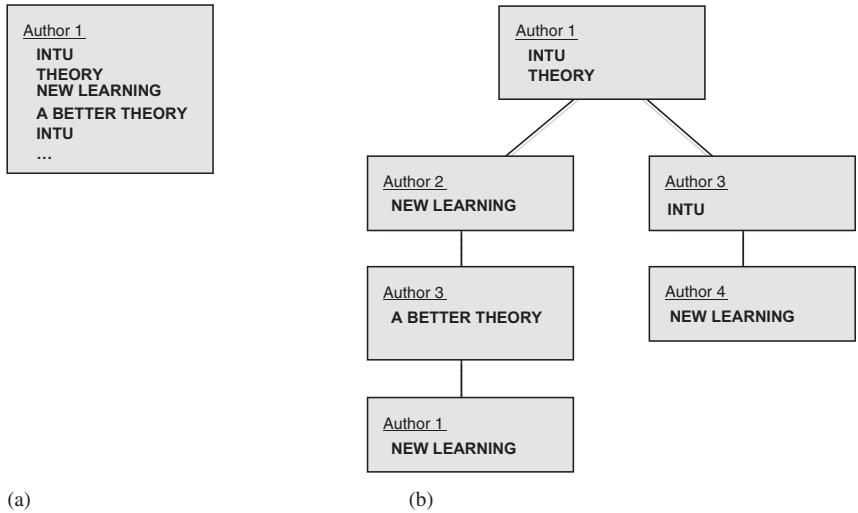

FIGURE 9 (a) An individually authored learning cycle compared to (b) a distributed-authored learning cycle.

Because the KBC developers' approach involves notes focused on single knowledge objects, this permits learning cycles not only to be constructed by individuals but also to be co-constructed by multiple researchers (see Figure 9). That is, it is not the case that each student needs to make the full range of knowledge moves within the learning cycle by himself or herself but rather that the knowledge advances can be made in a distributed manner. One student might propose an initial theory, a different student may independently carry out investigative work related to this idea, and yet a different student may contribute an insight that comes from synthesizing the investigative work with the contributions made by others. In this way, the classroom community is able to mirror disciplinary communities in which individual members make contributions, others act upon (improve upon, synthesize, argue against, etc.) such contributions, and knowledge is created and refuted through the collective workings of the whole.[4]

[4]In Bielaczyc, Kapur, and Collins (in press) we discussed these ideas in terms of *epistemic game play.* That is, one of the ways in which one might represent explanation-seeking inquiry within KBC classrooms is as a type of progressive investigation game. The Whitman teachers' learning cycle is actually one possible instantiation of the *progressive investigation game.* We argued that one of the distinctions between the epistemic game play of most classrooms, including many reform classrooms, and that of KBC classrooms is that in KBC classrooms the play takes place in the form of *multiplayer epistemic games* in which the knowledge moves can be made in a distributed manner by multiple participants rather than each player needing to make the full range of moves in a given game by himself or herself.

The reason for the divergence does not appear to be a lack of understanding or disagreement regarding the use of notes and build-ons on the part of the Whitman teachers. Instead, the divergence appears to be due to constraints and needs in the local context. As quoted at the start of the section, the teachers observed that "the intention of a note in that demonstration is more of a single purpose, whereas we have more of a dialogue. And many, many ideas are shared on one note." After noticing the difference between their notes and those shown in the demo video, the teachers discussed reasons why their use of notes differed. One reason given was that it would be difficult to have "single-purpose notes" with more than 100 students involved—"That's never been practical when you've got the number of bodies in a database." Over the course of their investigations, students entered multiple knowledge objects into their individual research notes (e.g., My theory, INTU, New learning). If 100 students were each to make separate notes for every knowledge object, the views would quickly become filled with notes (and, because the Whitman Team was not using the rise-above feature as a means of synthesizing ideas across numerous notes, the means for consolidating such notes would have been quite limited). Thus, the approach of having single notes with multiple entries served as a strategy for managing database readability and navigation.

What is interesting is that the teachers described how their approach was not simply pragmatic but also addressed particular learning needs:

Bielaczyc: Would you, if you had a smaller team of people, would you go towards having shorter notes do you think?

Mr. W: No.

Ms. S: I don't think so.

Mr. J: I don't think I would.

Bielaczyc: Why? I mean, what is this that you'd have in the notes that you—

Ms. K: Well, I see that in here, like this person has an opinion, then after that, they've got like a theory. So, there is that cycle of learning. If you have this thought here and have this thought here and this one here, it doesn't show a sequence of historical thinking. I think that's why we prefer having it all in one note where you can see that thinking and how it changes. With what, how many kids do we have? 120 some kids, or how many? It's just too much.

Mr. J: Well, the other thing is that that researcher, the kid, will want to go back and look at what they have. And if you have to continually open and close notes to see what you have, I mean, you can put them in a note reader but that's a lot of extra work, given the short time that we have to do stuff anyway. It's a time-saving device to be able to have it all in one note, just to be able to scroll the note and see what you've got.

Bielaczyc: Mm-mmh.

Mr. W: I think you're changing the purpose of your work with the database if you're going to go with a fairly single-purpose note, I would think. So, we just haven't chosen to make that shift.

The teachers felt that an advantage of having the entire learning cycle shown within a single note was that each time the note was opened it would "show a sequence of historical thinking. I think that's why we prefer having it all in one note where you can see that thinking and how it changes." This approach was viewed as supporting students in better understanding how to progressively improve ideas and in "self-monitoring the progression":

> Ms. S: Another thing that, and I'm not sure that I've talked about this before, but in listening to Mr. W, I learned to do this better myself and I think our kids are sort of like, as they go along training to do this, it's this self-monitoring of the progression of your thoughts, which is metacognition, but it's more internal than even saying to yourself "Well, how am I doing? What do I have to do next?" Which are things that you kind of teach the kids to do as they're learning. And the week goes to the next week, and the next week, they go along. But it's almost a constant internalization of, maybe that isn't right . . . you know, that there's almost a second self there listening to you learn and monitoring as it goes along. I don't know if this comes out when the kids are talking to you [to Bielaczyc], but I think for many kids it's there, that they do stop and, like Mr. W says, when you're sitting at the computer, you're just not typing all the time. You're kind of sitting there and maybe it looks like you're looking off into space, but you're thinking. You're contemplating about it. And so, they may be changing their idea even as they type something. And I've written enough now as a teacher and curriculum and stuff like that to know, to be able to recognize when that happens. But I don't know that we were, we thought about it so much before we got into CSILE and Knowledge Forum notes. Do you know what I'm talking about?
> Mr. W: Oh, yeah, definitely.

The teachers wanted students to better understand the "journey of their learning" through reflecting on their learning processes. They felt that it was important for students to experience the fact that learning takes time and may involve traversing many paths in order to build a deep understanding.

Thus, having the contents of the entire learning cycle in a single note always kept visible "what it takes to put a body of knowledge together that has some meaning to it." The continual visibility of the students' work as they worked in their note was viewed as supporting students in "self-monitoring the progression" of their ideas and helping to internalize the process of the progressive improvement of ideas. The same was true of the Whitman Team re-creation of the CSILE discussion notes—when the exchange was kept within a single note, the ongoing structure of the entire discussion was continually visible to the participants each time they opened the note. Although the series of notes and build-ons that formed the developers' approach could all be opened (either one by one or simultaneously) in order to see the contents of the entire learning cycle or a discussion, this

was not the default. In the developers' approach it was not necessarily "part of an ongoing structure that was continually there."

The other divergence found between the KBC developers and Whitman Team within the subdimension of student–teacher–cyberspace configurations concerned the use of the rise-above notes. The Whitman teachers explained how their weak understanding of the functionality and purpose of the rise-above notes had led them to choose not to use the feature. The rise-above notes feature was quite new at the time, and this weak understanding was clarified in the course of one of the Saturday reflection sessions through collaboratively examining demo videos provided by the developers. More resources and exemplars have since been developed in order to communicate the functionality of the rise-above notes.

Based on the case study, divergences were identified along the subdimensions conceptualization of student social identity and student–teacher–cyberspace configurations. Explanations have been proposed for why such divergences in teachers' designs occur. Through better understanding designs and their underlying reasons, design researchers can inform themselves about how the educational model has been understood and gain insights into contextual factors that need to be considered in implementing the model. This may lead to improvements in communicating about the model and/or refinements to the model itself. Divergent designs may also indicate that teachers are working to address local conditions that may not have been met with approaches that more closely resemble the goal state of the educational model. Such cases may have implications for the design of implementation paths. This aspect of the work is described in greater detail in the following section.

Using Divergence Analyses to Hypothesize Useful Transitional Steps

Up to this point, two analytic steps have been accomplished. First, a parallel-design matrix was constructed and used to identify specific divergences between the developers' and teachers' designs. Second, potential explanations were explored in an attempt to better understand why teachers may have implemented these particular design strategies. One type of explanation concerned whether teachers develop particular design approaches in order to address local constraints and needs. In some cases, teachers may be working to address local conditions that may not have been met with approaches that more closely match the goal state of the educational model. The teachers themselves may or may not specifically view the approach as a transitional step toward the goal state of the educational model. However, the teachers' intentionality does not change the value design researchers may gain in examining such an approach as a potential transitional step. It is important to go beyond determining whether a given design approach provides an assistive means of carrying out the model. Consideration

must also be given to whether the particular approach assists in the short term but may actually make it more difficult to move toward the model in the long run. Examining both the *assistive* and *prohibitive* aspects of various approaches permits the generation of possible transitional steps, which can then be tested further through classroom design. Through cycles of iteration, the process can support the construction of implementation paths. The original teachers may wish to collaborate in the process, or the work may be carried out by others.

Based on the Whitman Team case study, the design approaches that were used to address local needs in the Whitman Team classrooms can be investigated further. Specifically, for a given approach, what are the assistive aspects of the approach in transitioning toward the educational model? Does the approach meet particular needs that may not be met by starting with a design approach that more closely matches the goal state?

The Whitman students had an initial starting point that differed from the types of social interactions that they needed to be comfortable with in a KBC classroom. The Whitman teachers felt that the students who entered their classrooms in sixth grade did not necessarily respect one another or have a "feeling as if they belong together." They were faced with "a big order"—addressing the issue of *how to get a large group of middle school kids to construct communal knowledge if they do not view themselves as a community.* The Whitman Team needed to find ways to help their students "see each other as researchers" and develop a respect for "what each of them has to contribute to whatever the learning happens to be."

Such initial conditions are not unique to the Whitman Team. A common challenge faced in classrooms meant to mirror the workings of disciplinary cultures such as the KBC model concerns how to create socially safe contexts for publicly exploring ideas (e.g., Anderson, Holland, & Palincsar, 1997; Lampert, Rittenhouse, & Crumbaugh, 1996; Michaels, O'Connor, & Resnick, 2008). For example, the work of Magdelene Lampert focuses on fostering classrooms as mathematical communities, an approach that shares key similarities with the KBC model (Bielaczyc & Collins, 1999). In the course of a year-long fifth-grade mathematics class taught by Lampert, students were meant to learn the practices and norms of mathematical discourse. A conversation between a classroom visitor and the students revealed that students felt very uncomfortable challenging and critiquing the work of their peers. Lampert and her colleagues (1996) described various difficulties that arose "from mixing social interaction with the refinement of ideas" (p. 757), such as the feeling of "personal assault" (p. 744) and worries of being ostracized by others in the community. It is interesting that their analyses underscored that such difficulties occur not only in mathematics classrooms but in the mathematics profession and in other scholarly communities that work with critiquing ideas as well. Thus, engaging in the necessary types of social interactions can be very difficult for both children and adults.

Put simply, just sharing work in a common database does not make a class a community (akin to the idea that a community is not brought into being by "linguistic fiat," Grossman, Wineburg, & Woolworth, 2001, p. 943). Given the problems that can arise "from mixing social interaction with the refinement of ideas" (Lampert et al., 1996, p. 757), the social dynamics of a classroom might prevent students from experiencing the benefits of publicly exploring ideas and working together as a collective. Thus, the Whitman teachers' design approach of focusing on *person-to-person relationships* may provide a starting place for students. The idea is for students to start with viewing themselves and one another as resources for their individual investigations. Beginning in this way may provide a social foundation that allows for transitional steps toward developing the self-confidence, social trust, and skills in improving ideas that are needed to truly contribute as members of a knowledge-building community.

Another common challenge in bringing the KBC model to life in classrooms is engaging participants in working together to improve ideas. There are actually several aspects to this challenge. One is that "generating ideas appears to come naturally to people, especially children, but sustained effort to improve ideas does not" (Scardamalia & Bereiter, 2006, p. 100). In the words of the Whitman teachers, students also need to come to "understand what it takes to put a body of knowledge together that has some meaning to it." If students are coming from classrooms in which extended independent and collective work at building knowledge is not the norm, the challenge involves both "developing a disposition to work at idea improvement" (Scardamalia & Bereiter, 2006, p. 100) as well as developing strategies that enable participants to actually advance their ideas.

The Whitman teachers' design approach of having students work on carrying out the entire learning cycle within a single note may provide a transitional step that addresses such a challenge. As reported earlier, the teachers described how each time such a note was opened it would "show a sequence of historical thinking . . . where you can see that thinking and how it changes." They felt that this continual visibility of the learning cycle might help students to internalize the process of the progressive improvement of ideas. In elaborating on the value of having the learning cycle "continually there" in a note, one teacher highlighted how the "ongoing structure" scaffolded students' work in ways that permitted the students to work more independently:

> Because it was part of a structure that you followed, and you did it repeatedly. You might ask a kid why do you think so, and that was a question that teachers asked. And it wasn't always the teacher who asked the question of the kid then. When you're on the computer, it was the kid asking himself, well, what do I think. And I think it made kids more introspective as far as wonder and beginning to study. It helped them as well as the teachers to structure their learning and understand what it takes to put a body of knowledge together that has some meaning to it. There

> has to be a beginning. There has to be a place where you look to see if you were going anywhere. And that was a place to go. It also, and this came later on, we also realized that, as kids did this, it gave a place for misconceptions to be looked at and examined because you go back and you say well, did I used to think this way or do I still think this way, or boy, I thought that way but that really wasn't the way to think. So, there are a lot of different things that just happened because we had that as part of an ongoing structure that was continually there.

In the subdimension of conceptualization of student social identity, the teachers' design focus was on developing person-to-person relationships: We are here to help each other to learn. For student–teacher–cyberspace configurations, the teachers' design focus was on single notes that follow the learning cycle and reflect the process of putting a body of knowledge together. Both designs center on individual investigations, with students encouraged to help each other with their research and to share what they are learning. Furthermore, the two design approaches complement each other. Because students have their own individual notes that trace the path of their research investigations over time, then each time a student opens his or her note, he or she is able to visibly reify the types of self-concepts described by the teachers: "people who are confident in their ability to put together ideas . . . I have something to contribute" and "important for them to understand that they have a lot of power in learning." In addition, because the notes are in a common online forum and students read the notes of others, when students open others' notes they also see a full trace of the investigative efforts of their classmates, providing a means for developing a perspective that

> this person sitting next to me is an important part of my learning . . . They have to see each other as researchers, and they have to respect what each of them has to say and what each of them has to contribute.

In this manner, and working in tandem, the two design divergences may help students understand the processes of building knowledge while also establishing social trust and respect through developing a better sense of themselves and their classmates as able learners:

> Ms. K: Reflection is a way for them to see where they started and where they're at now. Look through their information, how much they've discussed. So really the reflection is really for them to synthesize all their thinking. Putting it together, see where they've come from. And I think it's most important for them to think about where they were and where they are now.
>
> Bielaczyc: What do you think they gain by seeing where they were then and where they are now?

Ms. K: Because if they do feel that they're being productive, they are learning, I think the next time, then, it becomes more important to them. So that they seem to even work harder for the next time that they're in the database.

Mr. W: Well, I think to add on to what Ms. K said, if they're doing any kind of thinking at all and they look at, OK, this is what I thought before and this is what I think now, and then if they ask themselves a question, well, how did I get from A to B? And they start putting it together and say, well, I really did that sort of on my own. I was able to raise some questions. I was able to pull things in that I wanted to find out. I didn't even have to rely on anyone else. If that kind of a realization starts happening for them, well, that can be a positive. That going to school and learning is not just something being done to them, but going back to what I said before, that they have a real integral part in this and that they are indeed capable of doing this thing called learning, whatever it happens to be. And it might surprise them. They say, gee, I didn't know I could do that. It's really interesting.

. . .

Ms. S: And when kids see where they were when they began and see where they are now, it is theirs. And with that comes that sense of ownership. The same things that happen in school, in writing workshops, with groups of teachers, in seminars or writing workshops, when you take something that has just been a fuzzy question maybe, and just something that kind of wormed out of your mind . . . so you're continually raising more questions and that they lead you someplace. You did that. And it's individual ownership. And that is so rare in school settings. . . . I think that happens for kids when they reflect and see their journey of where a kernel of an idea has come out and then actually took that someplace, and did something with it. So, to me, ownership is at the basis of everything about knowledge building.

With regard to the potential assistive aspects of the Whitman teachers' designs of social infrastructure, the design approaches may help students move from viewing school as "something being done to them" or as a place where "they can shrink up and not be seen or not be heard" toward helping students develop "ownership" of the learning process and agency in working together with peers toward improving ideas. The teachers felt that keeping visible the trace of the process in a single note permitted a constant reflection space for students to "see where they were when they began and where they are now" that helped them to develop confidence in their capability to learn. Through being supported in (a) seeing themselves and one another differently and (b) seeing what it takes to put a body of knowledge together, students may come to see themselves as part of a community that is able to build knowledge.

With regard to assistive aspects, the two specific design approaches appear to provide a means of creating transitional steps that address problems that have been found to arise in creating KBC classrooms. The next step is then for design researchers to consider whether a particular approach to addressing a need in the short term may actually make it more difficult to reach the goal state (i.e., are there *prohibitive* aspects of the design approach in transitioning toward the educational model?). This involves a consideration of issues of consistency and bias across the system of dimensions in the Social Infrastructure Framework.

In order to illustrate what is meant by considering prohibitive aspects, I present a contrasting case involving a different transitional design approach introduced by the Whitman teachers in the beginning of the sixth-grade year. In a conversation that took place during seventh grade, the teachers expressed concern about whether the way that they had introduced Knowledge Forum at the start of sixth grade may have adversely affected students' understanding of knowledge building. I include the dialogue between the teachers here in full in order to show how teachers explicitly discuss points related to consistency and bias (refer to the underlined text in Table 2). The exchange also highlights how interrelated the dimensions of the Social Infrastructure Framework are, as teachers discuss the tight linkages among design considerations such as classroom practices, cultural beliefs, and teacher roles.

In the excerpt, the Whitman teachers discuss how they introduced students to Knowledge Forum in sixth grade using a "response to literature" approach. Students worked in a similar manner to a book discussion group to share ideas about the common books that they were reading in language arts. The teachers worried that they may have unwittingly introduced an approach that worked at cross-purposes to helping students understand the learning cycle that they felt is central to knowledge building. The response-to-literature approach involved a "sharing of ideas" in which students "[wrote] about [their] responses" and talked "with each other about what's going on in the book." They contrasted this with the learning cycle, which they felt is like "the scientific method," involving "inquiry" and being "a researcher and [trying] to find ideas an answering questions." The teachers felt that these two approaches were "clearly different."

The problem was not in responding to literature per se. At a later point in the reflection session, the teachers discussed how they could design a knowledge-building approach to working with common books in language arts (involving shared inquiry into disciplinary problems). Instead, the excerpt in Table 2 points to how this particular transitional design approach led to inconsistencies and tensions among various elements in the dimensions of the Social Infrastructure Framework as compared with the goal state of the KBC model. The response-to-literature approach offered assistive aspects in that it provided "an easy way to get them [students] used to finding their way around that particular piece of software and . . . it was something that we could do right away." However,

TABLE 2
Teacher Discussion of Initial Approach Used in the Sixth Grade

Teacher Discourse	*Commentary*
Ms. S: From the first week we get them in sixth grade, we work a lot with reading, response to literature. We read orally to them. We model the response by oral discussion. They take their ideas and we get them right into a database, and they're talking with each other about what's going on in the book, for them. And we spend hours and hours and hours, do a sixth- and seventh-grade experience, doing this. I think that also transfers to responding to ideas.	In the following discussion, the teachers describe how, in order to start students using Knowledge Forum in the sixth grade, they had students discuss books that they were reading in language arts—akin to a book discussion group.
Mr. W: I'm glad we've had the opportunity to bring those responses into the Knowledge Forum database. **In certain ways, however, that is tainted. Some of the learners, I'm thinking about what's appropriate in the Knowledge Forum database. I'm afraid that to an extent some of our learners have gotten away from the more or less scientific method that we've been using, the innovative, identifying what I already know, figuring out what I need to know, and going and researching to try to find answers to those questions.**	However, the teachers worry that the conceptualization of Knowledge Forum that may have been fostered by their approach to the literature database conflicts with the desired conceptualization—that of a *learning cycle* in which one's understanding is constantly revisited and knowledge is progressively improved ("scientific method" and "cycle").
Ms. S: The cycle— Mr. W: Yeah, that cycle. **The inquiry is not directly supported by the response to literature. I can see how they're very, there are kind of, they exist both, almost collaboratively, I suppose, they exist both separately and, you know, building our students as learners, but they are clearly different.**	Mr. W asserts that using the initial approach of a response to literature is "clearly different" from the inquiry approach that they feel is central to knowledge building.
Bielaczyc: Do you think that distinction is made explicit to the students? Mr. W: I don't think so. At least I don't think that we brought it out intentionally. Ms. S: So we need . . . So we need to **do some comparative analysis between the kind of approach to thinking about literature and expressing our response to literature and the building of knowledge in a content area?**	

(*Continued*)

TABLE 2
(*Continued*)

Teacher Discourse	*Commentary*
Mr. J: Yeah, but it's pretty tough, you know. **Many of our students are to the point where they're saying, a dog is a dog, you know. A dog is not a, you know, a dog sometimes and something else other times. You know, Knowledge Forum is Knowledge Forum, and so what do you want me to do? Do you want me to write about my responses or do you want me to go be a researcher and try to find ideas and answer questions?** [overlapping voices]—	Mr. J describes how they may have unwittingly set up two different conceptualizations and that students may not be able to make a refined enough distinction between the two ("a dog is a dog, you know. A dog is not a, you know, a dog sometimes and something else other times").
Ms. K: —might be difficult for them?	
Mr. J: I would think, for a good number of our students, that's going to be, **probably more muddying the water than being productive.** I just don't know because of course we haven't tried it.	
Mr. W: But I think it's something to give some thought to, **that they need to differentiate what they're doing on those kinds of databases.**	
Mr. J: And I think if I, going forward into sixth grade, you know, **where do I want to start with Knowledge Forum now? Do I want to start with Knowledge Forum on a response, everything response, and then bring in the scientific method ideal later? Or do I want to start with the scientific method or the research question scaffold and then bring in** [noise obscures].	Mr. J puts forward the question of how to design for future cohorts of sixth graders.
Mr. W: Well, just to reflect on why we did that, the response to literature was an easy way to get them used to finding their way around that particular piece of software and, you know, that helped us out immensely, and it was something that we could do right away. But I think that you bring up something that's really a legitimate point, something that we need to take a look at and needs to be examined, **because if you go back to the fundamental philosophy of what knowledge building is all about, the literature database is not really a knowledge building kind of, it's a sharing of ideas, but it's not really a knowledge building kind of thing.**	Mr. W summarizes the reasons that they introduced the transitional approach and the possible implications of such a design move.

Note. Boldface indicates discussion of points related to consistency and bias.

such a transitional step may have hindered students in understanding "the fundamental philosophy of what knowledge building is all about" because it engaged students in different types of practices, it engaged students in different conceptualizations of the purpose of the tool and of knowledge and learning, and it was guided by the teachers in a different way than the goal state of the KBC model. Furthermore, the teachers worried that because such initial differences were not made explicit to students, this might have posed difficulties in transitioning toward the KBC model: "What do you want me to do? Do you want me to write about my responses or do you want me to go be a researcher?"

Now consider the approaches used by the Whitman teachers discussed earlier. As seen in the analyses, such approaches are consistent with the KBC goal state across multiple dimensions of the Social Infrastructure Framework, excepting the emphasis on person-to-person over person-to-enterprise relationships and individually authored single notes that follow the learning cycle. Moving from carrying out the learning cycle as an individual to doing so in a distributed manner appears possible without disrupting the working of other dimensions in the system of social infrastructure. That is, the transition involves carrying out similar knowledge moves across the cycle (e.g., generating and improving theories, posing questions, sharing information from research, challenging and synthesizing ideas), but instead of the investigative work being carried out primarily by a single student, the process becomes distributed across participants (refer to Figure 9). Furthermore, as students come to better understand the nature of the enterprise that they are undertaking and establish social trust in one another as learners, the transition to person-to-enterprise relationships can also come to the fore while person-to-person relationships remain important. In both divergent subdimensions the transition toward the goal state is a matter of extension and emphasis rather than eradication and replacement by a more relevant conceptualization or method.

The assertion is that movements between the steps in an implementation path that require changes across multiple dimensions of the Social Infrastructure Framework (i.e., changes across an entire system) are more difficult to achieve, as incremental changes in certain subdimensions might be held back by the workings of the entire system. Unlike the response-to-literature approach, in this case the desired transitions do not require a large number of changes across other dimensions in the system of social infrastructure. Furthermore, the changes promoted in one subdimension actually reinforce and support the desired changes in the other.

In considering both assistive and prohibitive aspects, design researchers should also consider what factors determine when and how students are to make specific transitions. For example, in the sixth grade, the teachers began the year using the response-to-literature approach, but in the subsequent research units the investigative approach involving the learning cycle was used. Thus, the change was required of all students at the same time at the start of the research units.

However, as regards individually authored learning cycles, which then transition to distributed-authored learning cycles, it is possible for both types to coexist in the same database in the same unit without requiring other changes in social infrastructure. That is, it is possible for students to create notes using a distributed-authored learning cycle at any point, but the individually authored learning cycles can be introduced as the common starting place. Because change in social comfort is expected to occur at different times for different students, then such an approach supports *student-determined shifts* at the level of individuals rather than *time-specified changes* that impact the entire cohort. As students grow in their social trust and see one another as collaborators, they can work together on distributed-authored learning cycles.

In addition to considering the assistive and prohibitive aspects of particular design approaches, design researchers should also consider the following: *If these transitional elements were to be adopted as part of an implementation path, then what might the next steps in such a path look like?* It is interesting that, in working with the Whitman teachers, I was able to ask the teachers themselves to consider further transitional steps during one of the Saturday reflection sessions. In moving forward, teachers suggested engaging students in considering the evolution of the collective growth of knowledge in a similar way to the individual growth of knowledge that they had come to understand through the learning cycle. In examining individual growth of knowledge, students began the learning cycle by capturing their initial knowledge using the WITIK (What I Think I Know) scaffold. Later, students reflected back on this initial understanding in order to realize "what it takes to put a body of knowledge together that has some meaning to it." In order to be able to similarly reflect on the collective growth of knowledge, the teachers suggested that the students engage in a WWTWK (What We Think We Know) analysis in order to capture the collective's initial understandings. This analysis would start with students first constructing a WITIK in their own note, then reading one another's WITIK entries, and then engaging in a dialogue about what they think collectively (thus creating their WWTWK). In addition, the students would then work together to plan how they would carry out their investigations. The teachers decided that students should also create a web that showed the scope of the investigations and how the team members' investigations related to one another.

The teachers felt that engaging in these types of collective activities at the start of a unit would help students better understand where different persons on the team were coming from, would help students to appreciate the power of working together, and would provide a record to reflect back on at the end of the unit. The teachers also felt that the students should post the WWTWK and the web as background graphics on the team's view. In this manner, both would be visible as students worked in order to serve as a reminder of the investigative process and of working together to advance the growth of knowledge over time. The intention

was to provide a way for the students to focus more centrally on collective goals in carrying out their research rather than on the individual ownership and skills fostered earlier.

In considering the proposal for next steps in the trajectory (whether suggested by the teachers themselves or by the design research team), the design researchers would then consider the proposed transitional steps in terms of assistive and prohibitive aspects as well as further steps that would be needed to create the entire span of an implementation path leading to the goal state of the educational model. Thus, the process is an iterative one that supports design researchers in generating hypotheses that can be tested through design research processes involving embodying such conjectures in actual designs.

CONCLUSION

Bringing innovative educational models to life involves a variety of challenges, not the least of which is their adoption into classrooms with existing cultural norms and practices that tend to be quite different from the goal state of the educational model. This raises the design problem of "How do we get there?" (Kolodner, 2006). In this article, I proposed an analytic method to assist design researchers in investigating ways in which teachers bring educational models to life in their own classrooms. The method centers on examining the types of social infrastructures that teachers design in implementing a given model. Investigating teachers' designs of social infrastructure affords opportunities to explore more deeply both teachers' perspectives on a variety of elements involved in the educational model and particular contextual issues that affect implementation.

The analytic approach involves (a) applying a *double layer of design conception* that uses the Social Infrastructure Framework (Bielaczyc, 2006) as a means of characterizing both the developers' and teachers' designs and (b) examining relationships across this double layer of design. Places where teachers' designs diverge from developers' designs may indicate implementation areas where teachers have difficulty understanding the model, disagree with specific aspects of the model, or are working to address local conditions that may challenge the implementation of a particular aspect. If teachers have designed an approach to address local conditions, then the particular design may provide insights into contexts that are initially different from the goal state of the model. The analysis method then focuses on examining ways in which the teachers' design approach may serve to assist in transitioning toward such a goal state. Consideration is also given to whether the design approach assists in the short term but may actually make it more difficult to move toward the model. The analytic technique supports an iterative process of constructing an implementation path that can then be tested through classroom designs. Extending the design research methodology toward

understanding the critical elements that contribute to achieving the necessary shifts is seen as a means of informing subsequent efforts toward scaling up.

In order to detail the analytic approach, I grounded its use in an actual case involving teachers enacting the KBC model (Bereiter, 2002; Scardamalia, 2001, 2002, 2004; Scardamalia & Bereiter, 1991, 1994). The case focused on the Whitman Team and the ways in which the teachers' designs of social infrastructure could inform the creation of an implementation path. The teachers' designs provided a means of supporting students in taking ownership of the learning process and becoming confident in themselves and their peers as researchers. As an integral part of developing their self-understanding and peer relationships, the designs also provided ways for understanding the process and developing the skills involved in "putting a body of knowledge together." Through supporting the development of *both* social trust and the skills of knowledge building, the Whitman teachers' designs suggest a means of scaffolding a transition from contexts with little support for student agency and collaborative knowledge work toward the person-to-enterprise approaches involved in participating in a knowledge-building community. The work thus contributes not only to extending the trajectory of design research through the development of a new analytic method but also specifically to advancing understanding of how to support teachers in enacting the KBC model.

Beyond the KBC model, the problem of creating socially safe contexts for exploring ideas while learning the processes of inquiry is a challenge commonly faced in classrooms attempting to mirror the workings of disciplinary cultures (e.g., Anderson et al., 1997; Lampert et al., 1996; Michaels, O'Connor, et al., 2008). The work of Sarah Michaels and her colleagues on Accountable Talk (Michaels, O'Connor, Hall, & Resnick, 2002; Michaels, O'Connor, et al., 2008; Michaels, Shouse, & Schweingruber, 2008) contributes to deepening an understanding of ways in which teachers can shape classroom discourse in ways that lay the foundations for academically productive talk in such classrooms. The findings reported here add to such work by providing insight into ways to design supportive social infrastructure.

Clearly a question that is raised by the present article (and arguments made by Barab & Luehmann, 2003, for linking teacher enactments and design research) concerns how design researchers can best work with and learn from the actual designs that teachers carry out. Working out design decisions for a particular innovation can be a resource- and time-intensive process. One approach is to keep a case library of teacher implementations, often seen in work on best practices. However, it seems critical to move beyond static archives to an approach that supports continuous inquiry into the implications particular designs have for both theory and practice.

One possible approach is suggested by the work of the KBC development team itself. Over the past 25 years, the developers have created a set of social and

technical structures to support continuous inquiry into the creation of knowledge-building classrooms by developers, teachers, and researchers. These include an annual summer institute, virtual meetings that occur throughout the year, and the Knowledge Society Network—a Knowledge Forum database shared across teacher-researcher communities (Scardamalia, 2003b). The Knowledge Society Network is populated with examples, but it is not static repository. It is meant to facilitate inquiry among developers, teachers, and researchers and support the continual advancement of the community's understanding of the KBC model. Such an approach can lead to the formation of a knowledge-building community among critical stakeholders, thus supporting the creation of design-based research partnerships that not only aid in developing design knowledge but also help build human capacity for innovation (Design-Based Research Collective, 2003).

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