Chapter 12
Conceptual Shifts Within Problem Spaces for Knowledge-Building Practice Within a Teacher Community

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Introduction

This study seeks to explore teaching practice through an analytical, exploratory study, using multiple data sources to uncover problem spaces generated and explored by knowledge-building teacher community through their daily classroom experiences.

Knowledge-building practice places students' ideas at the center of the classroom enterprise (Scardamalia and Bereiter 2003, p. 1370); twelve knowledge-building principles (Scardamalia 2002) characterize the complex, interactive system that makes it possible to keep those ideas on a continual improvement trajectory. Knowledge building has continued to grow as an area of intense research along with an increasing awareness of knowledge creation. However, while significant advances are being made in knowledge building (see, e.g., a recent special issue of *Canadian Journal of Learning and Teaching on Knowledge Building* edited by Egnatoff and Scardamalia (2010)), little is known about how teachers engage in knowledge-building practices and create the pedagogical advances associated with it.

This research takes advantage of a unique context – a school that has adopted knowledge-building theory, pedagogy, and technology for more than a decade and where innovative practice has become an integral part of the school's culture (Bielaczyc and Collins 2006; Zhang et al. 2010). It thus provides multifaceted and rich accounts of knowledge-building practices. Data sources include (a) teachers' knowledge-building practices in their classrooms, sampled over a full school year; (b) negotiated understanding of knowledge-building practice, as represented in weekly teacher meetings over the same school year, including reflections of their classroom actions; and (c) teachers' personal reflections, as

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conveyed in their journals. Using these data sources, it is possible to explore teachers' understanding of knowledge-building practices as individuals as well as a collective endeavor and to address features of teachers' individual and community interaction that make these practices sustainable and more likely to lead to improved classroom practices. A problem space model is proposed to frame the research questions that define the investigation into knowledge-building practices.

The research question is: "How do knowledge-building teachers, as individuals and as a community, construct and explore teaching problem spaces related to knowledge-building classroom practice?"

Literature Review

Knowledge Building, Adaptive Expertise, and Reflection-in-Action

Knowledge-building practice requires teachers to continually make decisions using students' ideas as a constant source of new information to transform the classroom into a community of knowledge-advancing members (Brown and Campione 1996; Zhang et al. 2009) grounded on the knowledge-building principles. In these contexts, teachers operate as designers, in the same reflective manner as in design professions requiring deliberative processes that emphasize intentions, plans, and mental effort in learning (Bereiter and Scardamalia 1993).

Knowledge-building practice relies on teachers' understanding and interpretation of knowledge-building principles (Scardamalia 2002) and their translation of these principles into daily practices. It assumes that teachers can make a shift from procedure- to principle-based pedagogy. Principle-based action requires adaptive expertise, a form of "expert knowledge that supports continual learning, improvisation, and expansion" (Bransford et al. 2006). Thus, there is a strong connection between knowledge-building practice and adaptive expertise to negotiate between innovation and efficiency – a connection that is essential for understanding the problems teachers identify as important and the solutions they generate.

Extending from this, reflection-in-action (Schõn 1983) has been postulated as a necessary method to develop adaptive expertise, and likewise, adaptive expertise is a necessary condition for reflection-in-action. Thus, concept of reflection-in-action, as contrasted with reflection-on-practice, has been widely adopted in education and, as elaborated in this study, represents an essential component of an idea-centered classroom. However, there is little empirical data on this aspect of teachers' work (Munby and Russell 1992). Common criticisms of reflection-in-action are that its conception does not consider the "hot and rapid" responses required of teachers in messy and chaotic situations (Eraut 1995) and that the nature of the professions (i.e., architecture, design, music performance) described in Schon's work deviates from that of teachers' work in real classrooms. It is likely that, without a set of

principles to govern their teaching and learning, teachers would not be able to perform reflection-in-action on core pedagogical issues. This assumption sets the context for this study as teaching and learning problems are complex and ill defined and require fast-paced decision-making.

General Theory of Problem Solving

Within the problem-solving literature, problem space (Newell and Simon 1972) is a representational concept used in this study to frame the way we understand teachers' thinking in generating and exploring problems in their daily work. A premise pursued in this study is that the nature of teachers' work within these problem spaces enables or thwarts teachers' problem analysis, their shift from procedure-based action to principle-based reflection-in-action, and development of adaptive expertise. The concept of a problem space is generally used to understand how problem solvers move toward their goals through a series of actions, broadly categorized along two dimensions: (1) generating the problem space and (2) exploration of the problem space. The first process includes cognitive processes such as finding the problem, constructing the problem, and reflecting on the problem. These problem-solving processes are distinctive for complex and ill-defined design problems, as contrasted with well-structured problems. Typically, teachers, along with other problem solvers, oversimplify the situation to avoid complexity and address the problem in the time available. They mostly react to events that present themselves and require immediate action, such as classroom management and the failure of students to comprehend a curriculum goal. For other pedagogical issues, they tend to make decisions intuitively, without much consideration of "trade-offs" between new possibilities and efficiency (Dillon 1982). In most cases, the decision is quick and routinized; consequently, there is no attempt to problematize the situation, let alone to consider new possibilities. Follow-up reflection, which comes after the decision is made, is then at best an exercise in rationalization rather than deliberate reflection-in-action. Understanding problem spaces as teachers construct and explore them is essential if we are to encourage reflection-in-action and adaptive expertise in teaching.

The following section provides a brief overview of the concept of a problem space, a space for problem solving, with focus on complex and ill-defined design problems and various accounts of teacher problem spaces.

Problem Spaces in Teaching and Learning

A classical view of problem spaces for teaching focuses on management, effective delivery, and engagement of students in meeting curriculum and teacher objectives. As suggested by the pedagogical decisions to be made in the Skillful Teacher model

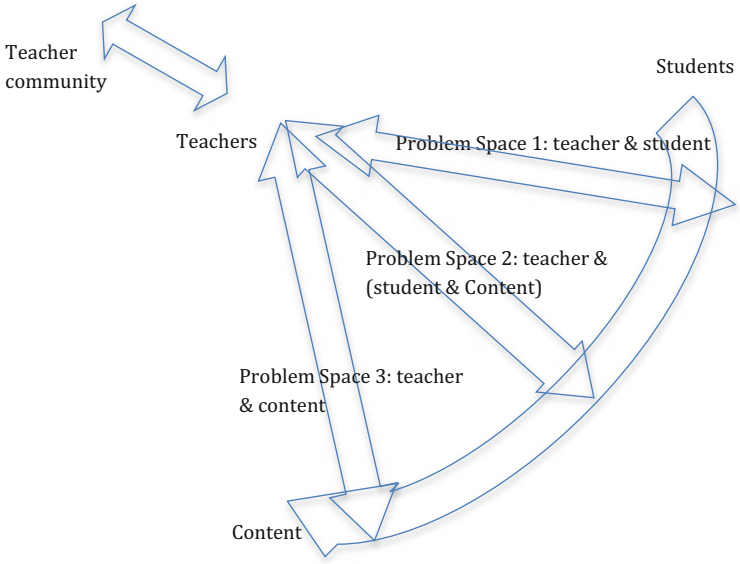

Fig. 12.1 Relational view of problem spaces (Lampert 2001)

(Saphier et al. 2008), the effort focuses more on procedures to be implemented. Saphier et al. (2008) presents a Skillful Teacher model that consists of four main problem areas – classroom management, instructional strategies, curriculum planning, and motivating students – that a good teacher has to negotiate before and during lessons.

On the other hand, Lampert (2001) proposed a relational view of problem spaces for teaching using relationships among teachers and various aspects of teaching and learning to characterize teaching and learning problem spaces (Fig. 12.1). According to Lampert (2001), teaching actions proceed simultaneously in relation with students, content, and the connections between students and content:

> This relationship is a "problem space" in the work of teaching. Working along the practice arrow that connects my work with my students, I can use them as a resource to solve the problems of my practice. They can also constrain my actions and hinder my efforts to support their learning. (p. 31)

Knowledge-building classrooms present unique problem spaces that require a relational perspective. Knowledge-building practice is only possible when a teacher develops an understanding of the 12 principles that define this pedagogical model, and deep understanding requires a relational perspective. The relational model is broad in scope and conveys well-known classroom problem spaces. The knowledge-building principles require a relational perspective so an attempt is made to map the socio-cognitive and technological dynamics of these principles onto the relational model. Toward this end, designs and strategies as set out by Zhang et al. (2010) and elaborated in Table 12.1 (column 1) are used to explore the

problem spaces that teachers have to construct and explore to bring about idea-centered pedagogy. Table 12.1 shows how knowledge-building principles can be mapped onto the relational perspective.

This relational model/knowledge-building principle mapping suggests the possibility of a further mapping onto the skillful model problem spaces that deal broadly with curriculum/standards, interaction patterns among peers-teachers-students, classroom structures and management, and student characteristics as they bear on matters such as inclusiveness and individual differences.

A Centrist to Relational Model of Action in Five Educational Problem Spaces in Advance Knowledge-Building Practice

Building on a variety of models of teacher thinking and development, a problem space model is developed and tested in this study, specifically geared to the development of knowledge-building practices. This model posits three pedagogical shifts resulting from advancement from centrist to relational perspectives in each of the five problem spaces: curriculum/standards, social interaction, student capability, classroom structures and constraints, and technology. Table 12.2 provides an overview of the shifts accompanying each problem space.

The model is used to guide data analyses from teacher interviews, journal entries, contributions to weekly teacher meetings, and classroom observations and serves to convey how knowledge-building teachers differ from other skillful teachers in the principal shift from a centrist to relational (or systemic) perspective in each problem space.

Methodology

Research Approach

The research used a qualitative approach, adopting the design of a case study with embedded unit (Creswell 1992; Yin 2003).

Data collection methods included:

1. Teachers' meetings: The researcher attended the teachers' weekly knowledge-building meetings, which lasted approximately 60–90 min and typically included all teachers in the school.
2. Classroom enactments: Three teachers were selected as the focus of in-depth case studies in which the researcher observed a minimum of an hour of each teacher's classroom interactions each week. This hour was either a knowledge-building discussion (a classroom conversation that the teachers and students

Table 12.1 Teachers' design and strategies to support knowledge-building principles

Principles for design and strategies in a knowledge-building classroom (Scardamalia 2002; Zhang et al. 2010)	Relational problem spaces
Real and authentic ideas: Teacher supports students in identifying problems that arise from students' efforts to understand the world and creates opportunities for students to pursue sustained creative work surrounding these problems	These principles can be translated into practice by first viewing and maintaining the relationship between teacher and students differently, that is, what guides the way in which the teacher supports, understands, and builds relationships with his/her students? These problem spaces in which teacher construct and explore includes: Managing social interaction Building students' capability Creating conducive environment (physical space and technological space) Using classroom structures and overcoming constraints
Collective responsibility for community knowledge: Teacher creates a learning environment where all students are legitimate contributors to the collective goals of the class and where their ideas are valued and they then take high-level responsibility for advancing the collective knowledge of the entire class, not just for their individual learning	
Democratizing knowledge: Teacher empowers all students as legitimate contributors to the shared goals, so that all take pride in knowledge advances of the community. Teacher promotes a culture where diversity and differences are viewed as strengths, rather than as leading to separation along have/have-not lines with respect to knowledge	
Symmetric knowledge advancement: Acknowledging that expertise is distributed within and between communities and team members	
Improvable ideas: Teacher treats ideas as improvable, rather than as simply accepted or rejected, so students continue to work on their ideas to improve the explanatory power, coherence, and utility of ideas	These principles can be translated into practice by first reviewing the relationship between teacher and content differently: What guides the ways in which the teacher works with the content and the school curriculum? The problem space in which the teacher constructs and explores includes: Managing curriculum goals and standards Building students' capability Making use of school structures and overcoming constraints
Idea diversity: Teacher helps students to understand that knowledge advancement depends on the diversity of ideas. Teacher helps students identify and bring related ideas together, including those that stand in contrast to each other, to help improve their understanding of an idea	
Constructive use of authoritative sources: Teacher and students access and critically evaluate authoritative sources and use them to support and refine their ideas, not just to find "the answer"	

(continued)

Table 12.1 (continued)

Principles for design and strategies in a knowledge-building classroom (Scardamalia 2002; Zhang et al. 2010)	Relational problem spaces
Pervasive knowledge building: Teacher opening up the inquiry space, acknowledging that knowledge building is not confined to particular occasions or subjects but pervades mental life, in and out of school and across contexts	
Knowledge-building discourse: Teacher and students engage in discursive practices that not only share but transform and advance knowledge, with problems progressively identified and addressed and new conceptualizations built	
Rise above: Teacher allows students to work with diverse ideas in complex problem spaces; they transcend trivialities and oversimplifications and work toward more inclusive principles and higher-level formulations of problems	These principles can be translated into practice by reviewing the relationship between the teacher and the student-content relationship: That is, what guides the way in which teachers manage learning outcomes, expectations of students, and assessment?
Epistemic agency: Students set goals, assess their work, engage in long-range planning, monitor idea coherence, use contrasting ideas to spark and sustain knowledge advancement, and engage in high-level knowledge work normally left to the teacher	Assessing and managing students' capabilities Creating a conducive environment (physical space and technological space)
Embedded and transformative assessment: Teacher designs and makes use of assessment as a way to advance knowledge through identifying advances, problems, and gaps as work proceeds	Making use of classroom structures and overcoming constraints Ensuring availability of information and resources in environment

referred to as KB Talk that focused on getting students to build on one another's ideas) or a session where students worked on Knowledge Forum®.[1]

3. Written journal entries: Notes posted on Knowledge Forum® by the classes and reflection notes posted by the teachers were analyzed to provide a complete and accurate description of the classroom activities.

[1] Knowledge Forum® is the second generation of Computer-Supported Intentional Learning Environment (CSILE) (Scardamalia et al. 1989). It is an asynchronous discourse medium where students and teachers author or coauthor notes that include multimedia elements, ideas, models, problems, plans, and data. Users can create graphic views as workspaces to hold these notes. Knowledge Forum also provides supportive features such as build-on, annotations, reference links to one another's notes, and rise above to allow users to organize and summarize the collective ideas.

Table 12.2 Three pedagogical shifts resulting from advancement from centrist and relational perspectives in the five problem spaces

Surface to deep	Routine to adaptive	Procedure based to principle based
Advancing from a centrist (C) to relational (R) perspective involves a shift from focus on obvious or evident features to ill-defined problems, big ideas, and promising possibilities	Advancing from a centrist (C) to relational (R) perspective involves a shift from routines to adaptive flexibility and novel approaches	Advancing from a centrist (C) to relational (R) perspective involves a shift from procedure-based actions to principle-based reflection-in-action
Curriculum/standards (C/S)		
From predetermined, fixed curriculum content and topic analysis to deeper, more expansive analysis of big ideas and promising possibilities in the light of students' ideas	From use of curriculum scripts to integration of students' ideas to support more flexible and novel approaches	From sequenced activities and procedures embedded in curriculum guidelines to work with principles to invent new, adaptive practices to advance curricular goals and student ideas
Student capability (SC)		
From attributing difficulties to lack of student capability to engagement of all participants in advancing shared goals	From individual differences and segregation to democratization of knowledge with student contributions leading to a whole greater than the sum of parts	From use of fixed-stage developmental sequences and benchmarks to turning over increasingly high levels of agency to students so they can exceed expectations
Social interaction (SI)		
From social interaction to get to know each other to social interaction as a sustaining force for exploration of complex, ill-defined problem spaces; big ideas; and new possibilities	From focus on activities and grouping arrangements to supports for distributed expertise and opportunistic processes that foster emergence of new ideas	From use of procedures and social media for information sharing to design and use of new forms of social interaction to maximize idea improvement
Classroom structures and constraints (CS&C)		
From viewing time, assessment, class size as structures, and constraints that limit possibilities to viewing them as boundary conditions that need to be crossed to explore new possibilities	From small group work and divided responsibility for a finished product to flexible roles and systems of support to allow participants to go where their ideas take them	From meaningful activities that fit within classroom structures and constraints to supportive, organic, and flexible structures that encourage participatory and distributed control and emergent collaboration
Technology (T)		
From familiarity with and ability to use common applications, functions, and web resources to ICT integral to daily work with all participants contributing to and	From use of technology for standard procedures and administrative convenience to reinventing classroom procedures based on special affordances of new media	From use of technology to implementation of best practices to combining principles, technology, and analytic tools to provide mutually supportive

(continued)

Table 12.2 (continued)

Surface to deep	Routine to adaptive	Procedure based to principle based
continually advancing shared goals		contexts for continually advancing high-level knowledge processes extensible to real-world contexts

The video recordings of teachers' meeting and classroom enactment were transcribed. The text, along with teachers' journal entries, was segmented into chronological order to describe flow of planning and classroom enactment. Qualitative analysis of all dataset, namely, teachers' journal entries, records of classroom enactment, and contributions in weekly meetings, was conducted to identify the problem space they identified and worked with in class.

Participants

As the purpose of the study was to examine an authentic and established knowledge-building culture and differences among teachers with different years of experience, the choice of participants and school was obvious. Participants were 13 teachers from the Dr. Eric Jackman Institute of Child Studies (Jackman ICS) Laboratory School, Ontario Institute for Studies in Education, a school affiliated with the University of Toronto. This school has successfully sustained knowledge-building practice for over a decade (Scardamalia 2002; Bielaczyc and Collins 2006; Zhang et al. 2010). The school currently enrolls about 200 students from nursery school (pre-K), kindergarten to grade 6, with 22 students on average per class. Most families come from a middle-class background.

Teachers Operating as a Community to Construct and Explore Problem Spaces Related to Knowledge-Building Classroom Practice

In this analysis, segments of individual case studies of knowledge-building teachers of three different sets of experience (i.e., novice, mid-experienced, and experienced KB teacher) in class were analyzed, with the teachers' discourse from notes collected during weekly meetings to reveal details on how different sets of problem space were negotiated by teachers with different years of knowledge-building experience.

Throughout the school year, all 13 teachers at Jackman ICS, along with the principal, met weekly to discuss advances and difficulties related to knowledge-building pedagogy. In these meetings, teachers with 1–8 years of teaching using knowledge-building pedagogy shared experiences and offered solutions to each other's problems. The meetings served as the primary means of acculturating new teachers into the school-wide knowledge-building community. Each meeting was framed by the following agenda: (a) identification of problems of understanding – this form of problem analysis has a strong basis in knowledge-building communities supported by Knowledge Forum and the theory-building scaffold; (b) knowledge advances; and (c) technology issues. The analyses in this chapter focused mainly on teachers' "problems of understanding" and interactions between teachers, coupled with individual teachers' decision and action to support knowledge advances surrounding those problems.

The problems teachers raised can be classified according to the five standard problem spaces: *curriculum/standards* (C/S), *students' capability* (SC), *social interaction* (SI), *classroom structure and constraints* (CS&C), and *technology* (T).

However, as is evident in the interchanges presented below, conversations shifted between these problem spaces at a fast pace, and the boundaries between "problems of understanding," "knowledge advancement," and "technological issues" became blurred, as group discussions led invariably to work that was deeply relational in nature. In terms of knowledge-building community for professional development, going beyond best practices reflects a shift from a centrist to relational perspective. And as the analyses below suggest, "going beyond" requires shifts as set out in Table 12.2. In line with these shifts, obvious or evident features of classroom activity were reconstructed in ways that had teachers dealing with ill-defined problems, big ideas, and promising possibilities; routines gave way to the generation of suggestions for novel approaches demonstrating adaptive flexibility; and procedure-based reflection was replaced by principle-based reflections. To convey how these meetings supported professional development, the excerpts from three meetings were analyzed below to show interchanges involving all teachers along with description of independent work of teachers in their classrooms. We see how they worked together to co-construct problem spaces, with attention to ways in which conversations allowed *all* teachers to stay on a continual improvement trajectory, as well as how similar ideas discussed at the meeting manifested in their classrooms and continued to be worked on and vice versa. Thus, rather than a unidirectional framework for professional development, in which more experienced teachers passed on their wisdom and "best practices" to the less experienced teachers, we see a teacher community as committed to engagement in knowledge building themselves as they were committed to engaging their students in these practices.

Three analyses of interactions presented below were selected to show how teachers consistently identified a significant teaching challenge and engaged in problem solving. These examples illustrate how this teacher community was structured to allow everyone to advance and how it contrasted with professional development designed to convey activity cycles, step-by-step routines, or other set

Table 12.3 Overview of problems discussed at teachers' weekly knowledge-building meetings that correspond to five problem spaces

Problems discussed, based on teachers' "problems of understanding"	Problem spaces
When and how should a teacher "wrap up" an inquiry?	Curriculum/standards (C/S)
How do we assess how much students have learned at any point during an inquiry, so that we know how much of the intended curriculum has been covered?	Students' capability (SC) Social interaction (SI) Classroom structure and constraints (CS&C) Technology (T)
What is the best way to handle superficial student work?	
How do we decide when to move on to a new topic of inquiry?	
What kinds of questions are needed to start a KB Talk?	
What is the best way to manage a Knowledge Forum view?	
How do we know if a knowledge-building principle is coming alive in the classroom?	
How can we encourage meaningful participation in a KB Talk?	
How do we respond to "the right answer" and not break the knowledge-building momentum?	
How can we ensure everyone participates in a KB Talk?	
Is there a best way to conduct a KB Talk?	
Are there steps to take in a knowledge-building class?	
When and how should we support "rise above"?	

procedures. For example, when a newcomer inquired about the "steps to be used for a KB Talk," more experienced teachers conveyed practices that were not step-like – practices that led them to continually refine procedures rather than follow a sequence of fixed steps. Further, as the experienced teachers reflected on the newcomer questions and offered advice, their reflections often led them to suggest novel approaches that they themselves had not tried but would consider in an effort to refine their own practices. Interchanges additionally convey ways in which the community acculturates new teachers into the school-wide teacher knowledge-building community, which operates on the basis of emergent rather than fixed goals. Table 12.3 provides an overview of the types of questions teachers pursued.

The three exchanges presented below span the five problem spaces identified in Table 12.2. And, as reflected in the discussions, proposed solutions, strategies, and contemplation of new approaches, addressing such questions requires a relational approach. Input from teachers with up to 8 years of experience resulted in discussions that moved flexibly between problem spaces and that demonstrated collective relational efforts.

Curriculum and Students' Capability Problem Space: How Can We Encourage Meaningful Participation in a KB Talk?

Knowledge-building discourse can take place anywhere, in face-to-face informal snack-time conversation, in a more formal classroom discussion, or in ideas posted on Knowledge Forum. This discourse is typical of knowledge-building communities and is perceived to go beyond sharing of knowledge, but more to refine, transform, and advance the collective understanding of the inquiry. From the data, it is clear that this group of teachers considered knowledge-building talk (KB Talk) an essential component of knowledge-building discourse and knowledge-building practices. As such, KB Talk was a common topic of discussion at these weekly meeting.

The following is a description of interactions that occurred when the least experienced knowledge-building teacher asked *what kind of questions* they should use to start their students on knowledge building.

Responding to this, Ronny, a teacher with 8 years of knowledge-building experience, explained that the questions could come in various forms and were rather emergent ("if something comes up then it becomes. . .").

Nancy, a teacher with 3 years of knowledge-building experience, shared her experience on how she got her students to connect their questions about rats to what they observed of their pet rat in class. She wanted students to come up with questions that they were genuinely interested in. She explained that there might be many reasons why students were not interested in a question and that the teacher had to understand those reasons to keep students motivated.

Ronny added that this process of students owning the questions might happen later, as students needed time to develop and process their ideas.

Nancy went on to share the example that occurred in her class when she tried to get the students to study rats and their living conditions. The students were asking why it was that the rat did not drink from the silver-colored container. They started to postulate some interesting theories such as "it is not warm enough" and "I don't think they like the silver." Once the students began to be engaged in working on something, they conducted research during their library period. Someone found out about using a special tray (the "pee tray") used by rats, and the students wanted to test their ideas. The teacher went to the hardware store to get more information and supplies that enabled student investigations.

Nancy asked how she could ensure that she was guiding the students in an inquiry involving important content knowledge. She felt that her role was to create an environment to support students in raising questions that interested them, and she had helped the process by building up the rooms with books on rats. She reported that she was not anxious about the content, suggesting that she was confident regarding her work on the *curriculum/standards* problem space which moved beyond content coverage. Her approach in this problem space was more adaptive to students' interest than to the curriculum script. She reflected on the way she should design lessons to ensure that students had sufficient opportunity to figure

out their question, connecting to *curriculum* to *students' capability problem space*. She was aware that she held control of how the lesson unfolded, as she reflected in her comments that the students came up to her to suggest what they should do next. Running through the various lesson ideas, she commented that "I didn't think I focused on content...I have not been anxious about the content at all."

Nancy was quite certain that the initial questions need not be constrained by content, but she was more interested to find out how to sustain knowledge-building momentum. Back in her own class, she explored the *curriculum/standards* problem space by setting an explicit curriculum goals that she wanted to achieve over the course of the year and by designing specific activities to get students to think and ask questions about water. Though she was prepared to embrace students' questions on water, she planned particular questions that she wanted to introduce in her class. She reflected that she "was toying with questions of an island and what would we bring [to an island]," and she felt these questions would be good for their study of water. She did not frame the class inquiry with her questions, but encouraged students to pose questions, and noted great *idea diversity* in their questions. This was consistent with her sharing at the meeting.

Zahra (the most experienced teacher with 22 years of teaching experience and 5 years of knowledge-building experience) reinforced the need to be aware of students' knowledge-building efforts. Interestingly, she conveyed what might be perceived as a dilemma in classroom design: "maybe interest starts to wane, maybe it is time to do a rise above, maybe...." Although her intention may not be clear, it suggests a clear relational goal involving students' ideas and curriculum goals, where there is no necessary disconnect between students' ideas and the *curriculum/standards* problem space.

This could indicate that more experienced knowledge-building teachers consider development of students' ideas as more important than content coverage. But the story is surely more complex. Students in this school were doing well on standardized achievement tests and other measures of educational achievement, and teachers had no reason to believe that there was a trade-off between development of students' ideas and content coverage.

Zahra continued to focus on the development of ideas as a guide to the curriculum problem space:

> It is how the ideas grow and – I am also thinking hearing the way the children talk – transcript showing the children in meaningful talk – that is not about content, but about how do you listen, how do their ideas grow: you might forget the content of the talk but it is the way [the talk is done].

Incidentally, Zahra was also the only teacher who started the year by providing enough time for the inquiry focus to come from her class. Zahra reflected in her independent classroom practice that she was "waiting to see what may emerge from the kids." She would start the year by collecting students' emerging ideas on the intended curriculum topic through a series of "morning message times," aligned to the *idea diversity* principle. She engaged the students in working toward common understandings and goals, engaging them in activities designed to create data to

help them generate and advance their ideas. For example, she had her students note the daily time of sunrise and sunset and talked about the trend of these recordings. She recorded these data on the side of the board for 2 weeks, during which time she and her intern recorded students' emerging questions and ideas. In the next class, Zahra then had her students contribute notes on Knowledge Forum. She took time to explain the rationale in terms of knowledge-building contribution and, at the same time, allowed her students to suggest other topics at every Knowledge-Building Talk. This was again consistent with what she shared at the meeting.

In sum, the above segment described what happened when a teacher with limited experience wondered what kind of question she could use to kick-start knowledge building (a centrist approach). Through interchanges with other teachers and sharing of actual classroom enactments of the teachers, it became evident that it was important to engage students in identifying questions, that the process was emergent, and that there was often no single question nor a need to be. Taking the sharing by the most experienced teacher and triangulating it with her practice, we could see that from her perspective, getting students to present their "problems of understanding" as a starting point for advancing curricular goals was essential, as was creating a supportive environment. The content would come, the ideas would grow, and the curriculum standards would be addressed (a relational perspective). This perspective was consistent with other comments she made and, with the fact that her students did well, as judged against curriculum standards.

How Do We Know if a Knowledge-Building Principle Is Coming Alive in the Classroom?

In line with their commitment to knowledge-building practice, teachers would regularly commit time during their weekly meeting to discuss specific knowledge-building principles. In one meeting, the knowledge-building teachers decided to explore the concept of "symmetric knowledge advancement" in relation to their own classroom work. This is an interesting segment that illustrates the teachers' struggle to understand the concept of "symmetric knowledge advancement," both for their own professional knowledge and for their students' learning. Their understanding and the degree to which they reconciled the principle with their practice varied significantly according to their years of experience.

Nancy (3 years of knowledge-building experience) began by questioning whether they, as a teacher community, were practicing this concept in their work. Extending from this discourse, Nancy, in her independent classroom work, had often tried to bring this principle alive among her students and her reflection showed that she was also deepening her understanding of the KB principle. For example, she was the only teacher who recorded an episode surrounding a misconception related to a student's theory that rains are produced by "cloud bags." Nancy generated various problem spaces after the emergence of the misconception.

She spent a great deal of time and effort trying to understand the root of the "cloud bag" misconception and to engage students in exploring ideas, rather than directly correcting the misconception. In constructing the *social interaction* problem space, she provided opportunities for the students to talk about two conflicting ideas that had been raised about the formation of rain. She also took time to talk to the student with the "cloud bag" idea, in order to try to identify the root of this misconception. She also got the students to send questions to a Chemistry lecturer in the university:

> Thought a lot about Kenny's statements and theories – how they might be of benefit to all our thinking – how I had maybe got caught up by his "cloud bag theories" and missed some of his bigger questions that could help us ("how can water be in the sky without a container?") – how we might protect him from staying in a polarized position.

After spending 3 months on a few explorations of the misconception that rain resulted from the formation of a "cloud bag" and explorations of related concepts, Nancy felt that the students had advanced as far as they could. She reflected on her role and felt that it might not be fair for her to exert her authority and directly correct the misconception after students had worked so hard to discuss their two views on how rain is formed, yet she felt she could not let the misconception spread within the class. There was no evidence that she searched for deep, underlying big ideas in the domain, which could perhaps have allowed her to engage students in discussions of their disparate ideas, or perhaps she had exhausted the possibilities within her own understanding of weather and rain and was unable to find a connection between the "cloud bag" theory and a scientific account. In any event, she corrected the "cloud bag" idea, and this discussion ended shortly after that. It is evident that Nancy was continually attempting to translate the knowledge-building theories into action in her class, which was consistent with her interest in expounding the theories at the teachers' meeting. Back at the teachers' meeting, Nancy drew an analogy to themselves as teachers, advancing their knowledge both in class and within this teacher community.

Zahra (5 years of experience) created another problem space by asking if there were real communities that achieve such symmetrical advancement. The more experienced teacher, Ronny, shared the original definition of "symmetric knowledge advancement" as one of knowledge-building principles and recognized his own struggle with this particular principle. Zahra advanced their understanding further by defining the technological dimension of the principle as how students' work across views on Knowledge Forum represented this principle. She continued to expand the idea that the measure in ATK (Analysis Toolkit available in Knowledge Forum) showed the kids were working across all the views and asked if that would be considered symmetric as well, that everybody was working on the same things (all the views) not just on theirs? In class, Zahra was also the only teacher who set clear goals to improve knowledge-building practice in a principled way, through the use of data from the ATK. She added, "[I am] really interested in using the Analytic Toolkit at the end of each day to inform my daily teaching. How the tools link to the [KB] principles. How they help the kids to understand the principles better."

As the meeting progressed, the teachers moved on to discuss another knowledge-building principle, *rise above*. Again, it elicited different interpretations from teachers with different years of knowledge-building experience. Nancy explained that for rise above to happen, an idea perhaps needs to exist in a "certain messy state" before it can move into a "higher-level formulation." Clara, a teacher with more than 5 years of knowledge-building experience, provided an explanation grounded in the framework of an idea-centered classroom. She explained it as a point of epiphany, where "certain things come together to move to the next step." Zahra pulled these ideas on *rise above* together and explained how this played out in her class:

> we are getting it, they want to learn how to make *Rise Above*, the idea of what helps them to . . . all those things seem OK . . .not just the epiphany part, we are experimenting, where are we now, so we keep going, it is the time where it comes together and then move forward again.

Alice, the teacher with less than a year of experience, described a superficial feature of an idea-centered event in her classroom, "someone said 'actually now I have changed my mind, I am going with Sage's (student) idea.'" This was her indicator that students were working with ideas, but she was not confident that they would work to improve their ideas. Rather, she felt that young children's mind swayed too easily for meaningful knowledge building to happen.

Exchanges like these show different interpretations of the role of knowledge-building principles in their practice, from a more abstract understanding and a philosophical explanation to concrete manifestation of the principle in the classroom. The most unique interpretation came from Zahra (5 years of knowledge-building experience), which connected explicitly to indicators on Knowledge Forum as well as its direct impact on her classroom work, "not just the epiphany part, we are experimenting. . .."

What Is the Best Way to Manage a Knowledge Forum View?

Knowledge Forum views are graphical representations of a space on Knowledge Forum designed to hold related notes together. They are constructed by participants to give greater meaning to the notes they contain. Every knowledge-building teacher would almost inevitably encounter situation where the number of notes posted on a KF view become too overwhelming for them. The following interaction occurred among teachers with 1–8 years of knowledge-building experience interspersed with classroom practice from individual case studies describing independent classroom practice on such problem of understanding. They provided accounts of the obvious or evident features identified by teachers with limited experience and showed how teachers with more experience addressed these matters and revealed efforts at principle-based action that became more direct with experience.

The conversation started with the "problem of understanding" from an inexperienced teacher on how to manage her class' Knowledge Forum view. The more experienced teachers were able to break down the problem to a deeper analysis regarding students' approach to their ideas on Knowledge Forum. The strategy adopted by the more experienced teachers involved adaptive flexibility to help students relate their ideas to the ideas of the class in order to resolve the problem before determining the procedures to adopt in class.

Nancy, with 3 years (mid-level) of knowledge-building experience, mentioned an obvious or evident feature of her classroom practice that she attributed to *students' capability* and *social interaction* – what she referred to as unproductive notes and a chaotic or messy view on Knowledge Forum. She attributed this, at least in part, to student inexperience in knowledge building:

> Part of what happened, of what is happening in database, it is really chaotic, we are also aware that we are just letting kids go in, not productive, [these] aren't the kind of notes that really help them to build knowledge; I also know that some of them are new, and so I think some of [them] are innocent like they are not realizing what the goal is.

She explored possible strategies, stating them in terms of procedures (use of data projector and whole-group activity), with the latter indicating a possible attempt to address the principle of *community knowledge, collective responsibility:*

> We have been talking about how next to help them work on the database. We did talk about using the data projector and . . . how we can get as a whole group; I felt it has to happen as a whole group because they all have to know it.

Moving on, the possibility that she was searching for a solution with a principle-based component was reinforced in the following comment:

> I am not sure I would like to work with them [that way], I want them to gain more understanding, the goal [is that] they are communicating.

It seemed that the teacher was trying to engage students in a way that would allow them to take more responsibility for their work, as which was consistent with her individual case study.

In class, Nancy had always been guiding her students in making sense of all of the questions and referred them to the following main questions, written on the board in class: Questions in major categories "Water and survival – why do we need water?" "About water: Why does a river move? Why is water wet? Why does it rain? Who made the first language?" Nancy went through the class database and picked up three ideas that she felt would help in advancing the class inquiry on water. In her journal entry she wrote interesting conversations in the database that would be worth following up on: (1) Clouds burst/don't burst – this could be a great topic for us to do more research on; (2) NHL hockey ice – I would love to find out more about this because I think the kids would be interested in it; (3) "Why is water wet?" – this is not a big topic, but I'd like to share the etymology of the word if I could find out something about it. Even though she had these ideas that she wanted to explore, Nancy did not use them to start off the KB Talk. She was guided by the principle of *real ideas and authentic problems*. She tried to create the conditions to

help students connect their talk to their ideas on Knowledge Forum, by projecting the Knowledge Forum view on the screen in class and asking students if they had any interesting notes on Knowledge Forum that they would like to discuss. This represents a conscious shift on the part of Nancy toward a more relational *curriculum/standards* (C/S) problem space – a problem space expanded by her contributions to that space. This is aligned to the *knowledge-building discourse* principle, in which everyone has a responsibility to contribute to the discussion.

Nancy followed up by sharing her experience with a similar problem. She was more certain and specific and clear that the procedure to be implemented needed to provide the infrastructure for the principle of *idea improvement*, giving ownership to students: "We have a lot of notes that are like yes, no, why are you saying that? – notes that didn't advance our idea." She went on to explore her strategies to achieve idea-centeredness: "We talked about every note that needs to have an idea in it. They can go right to the person to tell the person and talk to you." And shared her recognition of the need for continual improvement was evident in her follow-up comment: "Still in that process, I got some silly notes, this year this is a huge problem." Nancy, who started the conversation, continued to explore the problem that she and the more experienced teacher framed: "How did you get the students started to look at their own notes?"

Zahra, the more experienced teacher, continued to identify strategies for addressing the problem in light of *improvable ideas* principle, mainly from the students' perspective, and riding on the affordance of Knowledge Forum (*technology* problem space):

> We talked first, and they searched for their notes [that] they created just for this year. They put in the note, it is really easy. . .it also gives them a sense of, you can refine the search, the note they created is always there to be improved.

In class, Zahra would always be trying to get students' input onto the database and have a say about their notes on the database. She reflected about her practice, "I felt it was important for the children to have a chance to talk about what was going on the view." She reviewed students' posts frequently and constantly adapted her classroom design based on the emerging students' problems of understanding and set homework for the students based on their own problem of understanding:

> I went through the database and identify problems of understanding that they are curious about right now, and then the child who wrote the note, we wrote it on these cards so we can hang them up and have them off the database and see what we are up to. And then next week for their homework, on their sheet, they are going to write the problem of understanding that is most pressing to them now.

As the conversation continued, Rhonda (less than a year of knowledge-building experience) identified a challenge related to a scaffold support in Knowledge Forum, that students were "really hesitant to say that they have a problem of understanding." Ronny, the most experienced knowledge-building teacher in the group (8 years), responded according to his own experience by reconstructing the problem to let students own their learning:

> I made it clear that you are not responsible for any follow-up to the questions on the database; the question will be worked on if there is an interest, [it is] not something they need to work on, we were just getting them.
>
> ...No, I don't want children to think, oh, I have three questions and so I have to do three times more work; it is just to get all the questions and theory on there and see if people [are] interested.

Helen, a teacher of less than a year of knowledge-building experience, identified a similar issue with the "problem of understanding," though she reflected on her role as a teacher in a KB Talk, which is quite a relational reflection, but she continued to explore the format of the KB Talk. She wanted a procedure "so that all students feel successful and get a sense of themselves as someone who can participate in these talks." For example, in class, she got students to use duplo-blocks, with each plastic block building on another to represent building of ideas. The format was to ensure that everyone had an equal chance to contribute.

In this sequence, more experienced teachers were able to relate problems to the knowledge-building principles. In the case of "chaotic activities on Knowledge Forum view," they encouraged the less experienced teachers to look at the deeper feature involving concepts of students' views of their ideas on Knowledge Forum. In the case of students not wanting to admit that they had a problem of understanding, they encouraged them to look beyond and see how to get students to own the problems. In general, the strategies adopted by the more experienced teachers were aimed at helping students generate and improve ideas, relate their ideas to the ideas of others, and experience a risk-free, supportive environment for idea improvement.

Summary of Analysis of Meeting Transcripts and Individual Classroom Practice

Meeting transcripts revealed that teachers with different levels of experience construct similar problem spaces throughout their knowledge-building practice, with the more experienced teacher conveying a much more elaborate and extensive repertoire of strategies from a relational perspective. Records of classroom enactment of teachers within the group also showed a consistency between what they shared and their classroom practices. We see an indication of less experienced teacher shifting more readily back to centrist problem space in their class as compared to the more experienced teachers, though this needs confirmation from further analysis and case studies beyond what is presented here. For example, when the less experienced teacher asked about KB Talk, the discussion that followed indicated that all teachers viewed students' ideas as important, but the inexperienced teacher focused on format and the question to kick-start the talk. On the other hand, the more experienced teacher took a longer view of the challenge and focused on how to support idea generation and improvement in a community context. This kind of interaction opened up new possibilities for all teachers to advance their practices. Such interaction also illustrates what is meant by the claim that

knowledge building operates on the basis of emergent rather than fixed goals. The analyses of interactions among these teachers help to clarify how the co-construction and reconstruction of problem spaces in a teacher community facilitates shifts from centrist to relational perspectives, which then impact their independent practices in their classrooms. This represents an important consideration in teacher professional communities as well as a critical move from skillful practitioner to principle-based practitioner. Both of these factors would sustain work to elaborate deep features of problems and adaptive approaches to the generation and implementation of strategies, and principle-based reflection within problem spaces represents necessary components of idea-centered pedagogy.

Discussion

Changes from Centrist to Relational Perspectives Within Five Problem Spaces Constructed and Explored by Teachers with Different Levels of Knowledge-Building Experience

This study investigates the problem spaces constructed by teachers and the means by which they achieve continual improvement in their practices while fostering continual improvement of students' ideas. To accurately depict teachers' problem space, we need to capture more than snapshots of their practice so as to describe a continuum of events in and out of their classrooms. Understanding the shift in teachers' problem space in this approach helps to inform the design of teachers' professional development programs and professional learning groups beyond lesson design protocol and teaching strategies. Many current professional development efforts place an emphasis on what teachers should know and what their practice should be like, rather than on deeper analysis of the ways to scaffold the thinking and decision-making process of teachers in their day-to-day classroom work.

In addition to describing the problem space, to provide a theoretically consistent and empirically based understanding of the pedagogical shifts within these problem spaces that are necessary for knowledge creation to take place in classrooms, the analyses focus on an overarching dimension of change from a centrist to a relational perspective. The underlying belief, from the centrist perspective, is that the teacher's procedures and presentation of content represent the primary determinant of effective action in these problem spaces. The underlying belief for the relational perspective is that students' ideas and actions represent an underutilized resource and that effective action within these problem spaces requires turning over high-level controls to students so that they can act more effectively and responsibly. In essence, the relational approach requires effective action from both perspectives.

Both perspectives are meant to represent "good teaching" from a constructivist approach. The centrist perspective is reflected in the teacher's construction and elaboration of problem spaces that establish effective curriculum plans, social

interaction patterns, expectations, or other "best practices" as used by skillful teachers. The relational perspective is reflected as reinvention of those plans, interaction patterns, expectations, and so forth, as work proceeds to accommodate student input and shared responsibility. This centrist to relational shift is used to characterize three embedded shifts, all of which need to be made to foster knowledge-building pedagogy: (a) surface to deep interpretation of problems and processing of information, (b) routine to adaptive approach to classroom activities and student engagement, and (c) procedure-based to principle-based reflective action.

Accordingly, in knowledge building, construction and elaboration of the problem space represents a dynamic, ever-changing enterprise. This characterization of knowledge-building practice seems to be a double-edged sword. On one hand, embarking on knowledge-building practice naturally puts teachers in a position to design and innovate in a principle-based approach; on the other hand, it has also made formulation of professional activities for such practice extremely difficult due to its need of the implicit shift in practice. This difficulty is even more prevalent because any one point of enactment in a knowledge-building classroom, teachers could be conducting an activity that could look identical to that of a procedure-based classroom. The distinguishing factor is the teacher's focus of practice and her intentions behind the laboratory work. For example, a lesson that involves students testing a hypothesis through experimentation in a science laboratory could occur in either a principle-based classroom or a procedure-based classroom. A knowledge-building teacher would consider the follow-up activities in relation to student's formulation of a theory to be tested or from an exercise prescribed in a curriculum guideline. In view of these varied dimensions of teachers' cognition, description of their problem space becomes essential in understanding the relation between their explicit theories of action and the implicit theories underlying those actions (Argyris and Schõn 1974; Eraut 2000). In addition, considering these characteristics of classroom teaching and learning, detailed accounts of problem space are critical in addressing the immediacy and ongoing nature of teachers' work, especially as action unfolds (Arygris 1995). It is also worthwhile to note that the study of problem space also led inevitably to sharper notion of teachers' reflective practice in their natural setting because reflection-in-action and reflection-on-action are only possible if classroom problems are interpreted as ill-defined problems and not as well-defined problems within prevailing categories of classroom activity.

Once the problem spaces of teachers are shifted, we can be certain that there could be variations on the ways to integrate strategies and activities picked up at different professional development program into their knowledge-building practices. Some may choose to begin with a few basic activities; others may decide to try to integrate as many principles as possible. How much a teacher does and does not do in class is no longer important; what matters is that a shift is made and that the students' ideas take center stage in their budding knowledge creation practices.

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