Formative assessment for collaborative knowledge building in Chinese elementary science classrooms

Jingping Chen
University at Albany, State University of New York, chgping@gmail.com

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FORMATIVE ASSESSMENT FOR COLLABORATIVE KNOWLEDGE BUILDING IN CHINESE ELEMENTARY SCIENCE CLASSROOMS

By

Jingping Chen

A Dissertation

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Formative Assessment for Collaborative Knowledge Building in

Chinese Elementary Science Classrooms

by

Jingping Chen

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Abstract

The purpose of this study is to design and evaluate a technology supported collaborative formative assessment for knowledge building to help students reflect on the progress of their knowledge advancement and to sustain deeper inquiry. Guided by the knowledge building theory (Scardamalia & Bereiter, 2003; Scardamalia & Bereiter, 2006) and the formative assessment framework (Ruiz-Primo & Li, 2013; Wiliam & Thompson, 2007), a two-phase design based research was conducted to test and refine the assessment design in the six-grade science classrooms at a Chinese elementary school. The assessment was designed as a technology supported, student-directed formative assessment which focused on three major attributes of knowledge building: community knowledge advancement, social dynamics change, and individual cognition development. The results showed that unlike assessment to other inquiry practice that use the feedback of formative assessment to inform the inquiry moving toward fixed inquiry goals, in knowledge building the community collaboratively identify the emerging deeper/expanded goals through knowledge building discourse. The feedback about how to reach further toward these deeper goals continually direct the community’s immediate next step inquiry in the large picture of long-term outcomes. The results also suggested that with teacher’s sufficient guidance and support, the collaborative assessment practice was positively associated to the improvement of students’ knowledge building discourse, social network pattern and individual understanding.
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Chapter 1: Introduction

This chapter provides a brief introduction to this study. Background information about the research, the problem statement, and the purpose of the study are presented. The methodologies, including research design, data sources and data analysis method are also briefly introduced.

The Emerging Knowledge-Creating Civilization

A paradigm shift in the last two decades has led to the reconceptualization of learning as a social, cultural, distributed, and collaborative process rather than merely an individual act (Bereiter, 2002; Brown, Collins & Duguid, 1989; Kafai, 2006; Lave & Wenger, 1991). Instead of explaining learning only in terms of what is going on inside a person’s mind, scholars pay more attention to important things outside of the individual mind, including cultural background and resources, social contexts and practices, and communication patterns. This trend is compatible with the shift of our society from manufacturing to knowledge-based economies, within which innovation and the creation of new knowledge has become necessary for achieving prosperity—if not survival (Scardamalia et al., 2012).

Our society has entered into a knowledge based information age. Technology makes it possible for repetitive, predictable, routine physical and cognitive work to be replaced by computers and machines, and innovation and creation to become the chief development goal of nations and their citizens and organizations. In the global knowledge creation economy, technology-supported massive and frequent communication and collaboration is also making
organizational structures in highly productive firms flat rather than hierarchical. Decision making has become decentralized, and information is widely shared (UNESCO, 2005). Tasks in the work place are becoming more horizontal requiring different types of expertise and high level communications and problem-solving skills. Collaborative teams form within and across organizations, and work arrangements are flexible (Dickerson & Green, 2004).

Creation and innovation is achieved through systematic communication and collaboration instead of only as individual output. Most of the creative products are “too large and complex to be generated by a single individual” (Sawyer, 2006, p. 121). Many innovations, such as designing a new model of a Boeing airplane, developing a Microsoft operating system, or making a Hollywood movie, need hundreds or thousands of people from different countries to work together. Most scientific discoveries emerge from highly collaborative teams, and these scientific fields often work as a collaborative system.

Therefore, in an innovating and knowledge-creating civilization (Scardamalia & Bereiter, 2006), collaboration and communication have become the major theme of relationships among nations, institutions, businesses, and individual people. Systematic divisions of labor and collaboration among experts are required in a team, a company, an entire industry, or a research field. This civilization also demands creative and flexible people who can effectively collaborate to deal with emerging problems and create new knowledge.
Learning in Knowledge Creation Age

As Dewey (1938) noted, the purpose of education in any society should be “to give the young, the things they need in order to develop in an orderly, sequential way into members of society” (p. 56). From this standpoint it is obvious that the fundamental task of education is to initiate youth into the knowledge-creating civilization and to help them become better members of society. The Partnership for 21st Century Skills advocated that to succeed in work and life in the 21st century students need to develop learning and innovation skills, information, media and technology skills, as well as life and career skills. Among these skills, knowledge creation as a socially dynamic endeavor has been considered by many as the most important 21st century skill needed for the new era (Brown & Duguid, 2000; Csikszentmihalyi, 1999; Sawyer, 2007).

In addition, in the “information age” learning no longer happens solely within the traditional formal learning institutions such as schools and universities, but occurs anywhere, anytime and anyhow (Punie & Cabrera, 2006). New technologies, such as distributed cyber environments and cloud computing have made it possible for more people from different locations to share contributions, challenge ideas, continually update products, and advance theories (Zhang & Chen, 2012). The Internet technology also provides realistic means for learners to connect with civilization-wide knowledge creation and become contributors of knowledge (Scardamalia & Bereiter, 2006).
These all require systemic reform on pedagogical designs (Scardamalia et al., 2012). In particular, the focus of learning should change from knowledge transmission to knowledge creation. The former is seen as an internal, individual process that results in changes in beliefs, attitudes, or skills; while the latter is seen as creating or modifying public knowledge, which leverages and supports personal learning and understanding. Accordingly, the process of learning should also shift from shallow constructivism that makes students simply assemble information and compile it into multimedia presentation, to knowledge creation that requires continual commitment and efforts to improve these ideas, and ultimately to advance collective knowledge (Scardamalia et al., 2012). Technology supported learning environment and tools should be used to change roles of teachers and students in learning. The teachers should not be the center of information source anymore; every student can be an information source with the support of the Internet (through using search engine, wiki or library database) and presentation tools. Students’ learning methods should also be changed accordingly: instead of listening to the teachers’ lecture, conducting teacher required tasks and interacting with the teachers, the students can learn through many-to-many interactions and collaborations supported by the communication tools, conducting tasks that designed by themselves, and engaging in collaborative knowledge products advancement in the virtual public space (Hakkarainen, 2003; Laferrière, Montané, Gros, Alvarez, Bernaus, et al., 2010; Moss & Beatty, 2006; Oshima et al., 2006; van Aalst & Truong, 2011; Zhang, Hong, Scardamalia, Toe, & Morley, 2011).
Problem Statement

New pedagogies to develop knowledge-creating capabilities among 21st century learners require new approaches to assessment. As Shepard (2000) stated, how people define knowledge will decide how learning is perceived, what performance is presumed as knowing, and then in turn, determine what assessment should be adopted to evaluate the achievement. If knowledge is conceived as a social cultural artifact that is created by community members’ collaborative effort, then it is essential that corresponding assessments capture its nature and adapt to the needs of evaluating the advancement of this knowledge. However, existing assessment models often fail to measure the achievement of collaborative knowledge creation. Traditional assessment tools focus on individual learning processes and outcomes, and capture very little of the collaborative inquiry processes that continually evolve (Zhang & Sun, 2011). With individual knowledge advancement as the focus of assessment, the quality of students’ collaboration work is often neglected. Moreover, most of the assessments only serve as evidence that characterize students’ performance and progress (Messick, 1994; Mislevy & Haertel, 2006), not as a scaffold for future learning and knowledge creation (Bransford & Schwartz, 1999; NRC, 2000; Shepard, 2000).

In addition, in technology-supported learning environments, technology supported assessment tools are often designed as “external” evaluation systems that are imposed by teachers or third parties. Students are considered passive test takers instead of active agents, and the results of assessment usually are not provided to the students as feedback to inform their future learning. Even though new assessment tools are developed for inquiry-based
learning contexts, most of these assessment methods still remain as research tools that only serve researchers’ and teachers’ needs; they are often too hard or too complicated for students to interpret and utilize (Zhang & Chen, 2012). The implementation of technology supported assessment in varying educational contexts could also be a challenge. The technological tools need to be contextualized by the community members, so the use of technological tools will interact and integrate with the local cultural practices to facilitate a new learning culture (Zhang, 2010).

**Purpose of the Study**

The purpose of this study is to design and evaluate a technology supported collaborative assessment for knowledge building to help students reflect on the progress of their knowledge advancement and to sustain deeper inquiry. Guided by the knowledge building theory (Scardamalia & Bereiter, 2003; Scardamalia & Bereiter, 2006) and the formative assessment framework (Wiliam & Thompson, 2007; Ruiz-Primo & Li, 2013), the collaborative assessment design used in this study integrates formative assessment, technology supported group reflection on idea progress, and students’ portfolios to promote and document individual and group knowledge advancement.

The collaborative assessment design is tested and refined through a two-phase design-based research study conducted in two science classrooms in a Chinese elementary school. Data collection included online and face-to-face discourse, class observations, class videos, interviews, and students' pre-test and post-test results. Using case study method,
content analysis, and quantitative analysis, these data are analyzed focusing on the implementation of the assessment and the roles of the assessment in the students’ overall inquiry. The results of this study provide a new, classroom-tested assessment design that is needed for collaborative knowledge building practice.

Chapter 2: Literature Review

This review of the literature explores the current research on knowledge building and assessment designs, with the intent of informing an assessment design for knowledge building in the current study. First an overview of knowledge building theory is presented, and the history of knowledge building theory development is briefly introduced. Second reviewed are the essential aspects for knowledge building, focusing on the theories and practice about conceptual artifacts, idea development, community knowledge and students’ collective responsibility. Last examined is the theory and research on assessment for knowledge building, noting any effective designs and potential trends. Based on the gaps between knowledge building and assessment designs, a new assessment design for knowledge building is proposed. Details of this assessment design are illustrated, including its nature and guiding principles. Finally, the research questions are presented.

Knowledge Building Theory

In this section, the literature was reviewed as it informs an understanding of knowledge building theory. By reviewing its social-cultural epistemology stance, how knowledge building theory distinguishes itself from other learning theories was introduced.
The brief history of knowledge building provide a background of how the knowledge building theory stemmed from the real needs of the users in an collaborative online learning environment, and how it grows with the support of technology affordances.

**Brief history of knowledge building theory.** The term “knowledge building” was originally introduced into the educational literature in 1989 (Bereiter & Scardamalia, 1989, p.388). The research on knowledge building stemmed from Bereiter and Scardamalia’s research on intentional learning in 1980s, which supported by a computer-supported tool named “Computer Supported Intentional Learning Environment” (CSILE). The students’ experience and performance of building a collective database of their thoughts on CSILE inspired the researchers to reach further than promoting students’ cognitive ability on perceiving learning as a goal instead of an incidental outcome. They found that the students’ desire to belong to a community is a more powerful and sustaining motive than achieving individual goals. In this case, contributing to the collective knowledge becomes a social norm in the community, and CSILE can be a public space for the community members to realize their social values (Scardamalia & Bereiter, 2010).

Based on these findings, Scardamalia and Bereiter brought out the concept of knowledge building as collaborative creation of public, collective knowledge in 1990s. Currently, the well accepted concept of knowledge building was defined as “the production and continual improvement of ideas of value to a community, through means that increase the likelihood that what the community accomplishes will be greater than the sum of individual contributions and part of broader cultural efforts.” (Scardamalia & Bereiter, 2003, p. 1371).
This definition suggests that knowledge should be treated as community property rather than as individual mental content, and the collective work of community should be a sustained progress that aims at improving the knowledge itself rather than improving the contents of students' minds (Bereiter & Scardamalia, 2010).

The forming of knowledge building theory leads to the change of CSILE to Knowledge Forum, a new generation of knowledge building environment which focuses on improving collaborative knowledge. Student ideas are presented in distributed postings (e.g. notes) and responses (build-on notes) in extended online discourse. The centerpiece of the evolvement from CSILE to Knowledge Forum was the graphical view instead of a list of entries. To be more specific, on the CSILE views the notes are shown as a small squares, and the connections are represented by the lines between the notes. The authors can post their initial ideas as a new note, reply to an existing note to expand their ideas (these notes are called “build-on” notes), add a "sticky-type” note to comment on an existing note (annotation), or write a synthesizing note that contains a collection of other notes (rise-above) (See Figure 2.1). This graphic presentation of the knowledge building trajectories provided a higher-level representation of the community effort on knowledge improvement over time (Scardamalia & Bereiter, 2010). This collaborative online learning environment not only provided a public space for the community knowledge to achieve visual “out-in-the-world” existence, but also equip the individual learners tools and access to interact and contribute to the community knowledge.
Based on the practices and research in last two decades, Carl Bereiter and Marlene Scardamalia along with other researchers have made important contributions to developing a conceptual framework of knowledge building that captures its socio-cognitive processes and emphasizes collective knowledge advancement (Bereiter, 2002; Scardamalia & Bereiter, 2006; Zhang, Scardamalia, Lamon, Messina, & Reeve, 2007; Zhang, Scardamalia, Reeve, & Messina, 2009). Many researchers adopted this theory and made knowledge building an important research area for Computer Supported Collaborative Learning (CSCL).

![Figure 2.1. An example view created by Grade 3 students in Knowledge Forum. Each square icon represents a note. A line between two notes represents a build-on link (Scardamalia & Bereiter, 2006).](image-url)
CSCL is an area rich with research implications for the growing philosophies of social constructivist and dialogical theories (Lipponen, Hakkarainen, & Paavola, 2004). It focuses on using technology affordance to provide collaborative learning environment (Kreijns, Kirschner, & Jochems, 2003), facilitate collective learning (Pea, 1994), or advance group cognition (Stahl, 2006).

As an important form of CSCL, technology supported knowledge building environment inherits its basic goal of supporting collaborative inquiry activities, providing easy access to the knowledge resources from multiple fields and communities, and enhancing the practices of group meaning making. Various collaborative online and mobile environments have been developed to support knowledge building in different contexts, including publicly accessible internet and specially designed online platforms and tools, such as Wikipedia, handheld devices (Roschelle, Tatar, Chaudhury, Dimitriadis, Patton, et al., 2007; Dunleavy, Dede, & Mitchell, 2009), and 3D virtual, multiuser environment (Livingstone, Kemp, & Edgar, 2008). In general, technology contributes to knowledge building practice in the following aspects: (1) facilitating student work in many-to-many interactions; (2) integrating different forms of discourse (both online and face to face communications); (3) focusing on communal problems of understanding; and (4) promoting awareness of participants' contributions (Hewitt and Scardamalia, 1998).

**Essential Aspects of Knowledge building Theory.** The concept of knowledge building derives from social constructivism epistemology, which maintains knowledge as “a compilation of human-made constructions” (Raskin, 2002, p. 4) instead of “the neutral
discovery of an objective truth” (Castelló & Botella, 2006, p. 263). Knowledge building also echoes to Vygotsky’s (1978) social-cultural theory emphasizes a social nature of human learning, and rejects the notion that learning is just an internal process that occurs in individual mind. Scardamalia and Bereiter (2003) consider knowledge building as synonymous to “knowledge creation.” Creativity in this knowledge age is no longer a sudden illumination of isolated gifted individuals, but “joint cooperative activities of complex networks of skilled individuals” (Sawyer, 2006, p. 119). Moreover, to be considered as creative, any novel ideas or artifacts must be socially defined and approved. The complex social system includes field (systems of social networks) and domain (systems of language and conventions). Knowledge creation, in turn, is also a social endeavor that aims for the deepest levels of work with ideas, which leads to the emergence of new ideas and continued efforts to improve upon them (Scardamalia & Bereiter, 2003). This theory echoes with recent research on knowledge creation and innovation in knowledge organizations such as high-tech firms, scientific communities, and hospitals (Scardamalia et al., 2012; Zhang & Chen, 2012).

Besides its epistemological stance that highlights the social nature of knowledge, knowledge building theory distinct knowledge building from other learning theories from following aspects: “out-in-the-world” existence of the conceptual artifacts (the construction of community knowledge); sustained idea improvement (diverse ideas emergent from authentic problems, and continue evolve and refine into new forms); collective responsibility and epistemic agency (all participants are committed to contribute to the knowledge creation and deal with the problems in the process); and the interaction between the individual and
community knowledge (the community knowledge continually interacts with individual knowledge through knowledge building discourse).

“Out-in-the-world” existence of conceptual artifacts. The central concept of knowledge creation is conceptual artifacts, which is defined as discussable human constructions that serve a conceptual purpose, such as explaining or predicting (Bereiter 2002) borrowed Popper’s (1972) idea of three worlds as the basis of understanding cognition in knowledge building: World 1 consists of physical objects that are determined by the laws of physics (nature); World 2 consists of an individual’s beliefs and mental states (thinking and psyche); and World 3 is the world of cultural knowledge (culture and society).

Knowledge building and knowledge creation means working in World 3 (community culture and knowledge) for the advancement of conceptual artifacts, such as scientific theories, ideas and models. Conceptual artifacts share the following characteristics with the material artifacts, to include: (1) they have origins and histories; (2) they can be described; (3) they can be compared with other artifacts of their type; (4) they may be valued or judged worthless; (5) they have varied uses; (6) they may be modified and improved upon; (7) they may be a subject of discussion; (8) new attributes, uses, or defects may be discovered that were not foreseen when they were created; and (9) people differ in how well they understand them and in how skillful they are in using them (Bereiter, 2002).

Moreover, these artifacts have unique conceptual characteristics which can be used for rationalizing behavior. They could be scientists’ productions, or explanations and ideas developed by knowledge building community members. The idea of conceptual artifacts
made the concept of “knowledge building” (knowledge creation) clearly distinctive from “learning,” since the former creates knowledge objects (conceptual artifacts) and the latter leads changes in personal knowledge and skills.

To make it possible for the community members to work collaboratively on the conceptual artifacts, it is essential that these artifacts have “out-in-the-world” existence in the public space. The current knowledge building environment has many features to promote “out-in-the-world” existence of the conceptual artifacts. For example, Knowledge Forum provided a more visual view which shows the connections of the personal ideas (notes). Epistemological scaffolds such as “my theory,” “I need to understand,” “new information” embedded in note editing interface made the thoughts more evident; the build-on, annotation, and reference links constitute a graphic view of how the students are interacting and how the ideas are developing (Scardamalia & Bereiter, 2006; Scardamalia & Bereiter, 2010).

**Sustained idea improvement.** Knowledge building can be described as a process of community members’ collective work on advancing the conceptual artifacts (Scardamalia & Bereiter, 2010). The conceptual artifacts usually come from authentic issues, problems and challenges that drive people to seek new information and new understanding, such as students’ problems from first-hand observations, experience and experiments (Zhang et al., 2007). Then, students indicate their ideas in the public space (online knowledge building environment such as Knowledge Forum or face-to-face classroom discussions) to invite peer input. The community members will read them with scrutiny, and decide their next steps: challenge them, write build-on notes on them, annotate them, use them as references, or
ignore them. Then the ideas will be filtered spontaneously, and valuable ideas will become continually improved through comparison, combination, and alignment with other ideas (Scardamalia & Bereiter, 2006).

The knowledge building is a sustained, unfolding idea improvement process that invites all the community members’ collaborative work. This sustained, unfolded nature decides that the goals of the knowledge building practice should be emergent instead of fixed (Zhang et al., 2009). Constructivism usually aspires the learners to generate their own sub goals necessary to achieve the bigger goal, while the knowledge building community not only decides their individual goals, but also determines the emergent goals of the community’s next step inquiry through negotiation. This negotiation is a social process that invites all the community members’ contribution (Scardamalia & Bereiter, 2006).

The collaboration among the community members can be opportunistic and ill-structured, which is in line with an emergent perspective of knowledge creation (seeing understanding as emergent rather than strictly planned). This distributed, opportunistic collaboration may support the progressive knowledge building extended over weeks, months, or years (con). To make the idea improvement a sustained, unfolding process, students need to be empowered with the collective responsibility for continually advancing the community knowledge. They will progressively reflect on what they have achieved, and identify the focus for future inquiry (Zhang, Chen, Chen, & Mico, 2013).
**Epistemic agency and collective responsibility.** In educational knowledge building communities, community members are considered as “expert-like” knowledge creators instead of passive accumulators of ready-made information of the human mind. Their collaborative efforts on creating, developing, and criticizing conceptual artifacts is similar to what happens in the knowledge frontier of humankind, where the scientific community collaboratively works in World 3 to develop new theories and models (Bereiter, 2002). The “epistemic agency” of the community members is advocated, which refers to “the amount of individual or collective control people has over the whole range of components of knowledge building—goals, strategies, resources, evaluation of results, and so on.” (Paavola & Hakkarainen, 2005, p. 9)

The other dominant characteristic of the knowledge building community is the “collective responsibility” of the community members, which indicates the member’s commitment to contribute to the collective knowledge enterprise of the community, and willingness to work as a team to continually improve their ideas, rather than simply advance their own (Scardamalia, 2002; Zhang, 2007; Zhang, 2010). They will be willing to contribute their ideas to a communal knowledge space and share a commitment to improving ideas of value to their community. They also demonstrate commitment to deal with problems of goals, motivation, evaluation, and long-range planning that are often left to teachers in traditional schools (Scardamalia, 2002).

Zhang et al. (2009) proposed that the major components of collective responsibility in the knowledge building environment should include the following: (1) reviewing and
understanding the state of knowledge in the broader world, hence generating and continually working with promising ideas; (2) providing and receiving constructive criticism; (3) sharing and synthesizing multiple perspectives; (4) anticipating and identifying challenges and solving problems; and (5) collectively defining knowledge goals as emergent from the process within which they are engaged. This provides a useful framework for evaluating the quality of collective responsibility in the knowledge building community.

The basis for students to have epistemic agency and collective responsibility is the “out-in-the-world” existence of community knowledge (conceptual artifacts) and the sense that this knowledge can be continually improved (Zhang et al., 2007). Without these two elements, the students’ learning will be restricted within the individual minds and there will be no motive for the students to care about the goals, schedules and progress of knowledge building as a community.

The interaction between individual knowledge and community knowledge.

Scardamalia (2002) advocated that the aim of knowledge building is producing community’s collective knowledge. It is worth noting that collective knowledge is not just discussed in the literature of knowledge building; it has been a popular topic in Computer Supported Collaborative Learning (CSCL) research. The idea of collective knowledge can be traced back to Vygotsky’s (1978) contrast of development at the group level to the traditional psychological focus on individual learning. He pointed out that individual learners have different developmental capabilities in collaborative situations than when they are working alone.
Stahl (2006) listed some possible positions on the nature of community knowledge, including: collaborative knowledge building (Bereiter, 2002), social psychology (Resnick et al., 1991), distributed cognition (Hutchins, 1996; Solomon, 1993), situated learning (Lave & Wenger, 1991; Shumar & Renninger, 2002), activity theory (Engeström, 1999; Nardi, 1996), and ethnomethodology (Dourish, 2001; Garfinkel, 1967). The similarity among these theories is that they all admit that the group as a social unit can learn in different ways compared with individuals. Meaning making in groups is constructed by the interactions of the individuals, thus it cannot be seen as simple averages or sums of individual mental meanings, or an overlap of individual’s internal representations. Scardamalia and Beretier (2006) also stated that group learning is learning by groups, not learning in groups or individual learning through social processes.

Stahl (2000) advocated that the individual mind is indispensable in the social knowledge building process. He proposed a model that describes learning as a cycle of personal understanding and social knowledge building (See Figure 2.2).
As the diagram depicted, the cycle of personal understanding (starts from the lower left corner) is based on the tacit pre-understanding. The pre-understanding of the individual mind originates from the social context and interactions which include language, history, culture, social structures and politics. In other words, individual’s personal beliefs are generated on the basis of social-cultural knowledge, shared language, and external representations. Then the personal beliefs are articulated into language and enter the social process of interaction with other people and culture. Through social interaction, communication, discussion, clarification and negotiation, these beliefs become shared collective knowledge. The collective knowledge is objectified in cultural artifacts, and comes to life in personal understanding through interpretation. The culture imports individual
understanding, shaping it with ways of thinking, motivational concerns, and diverse influences (Stahl, 2006).

This model articulated the relationship between individual understanding and community knowledge: individual understanding provides both the starting and the ending point of the learning cycle; individual understanding itself is based on existing social cultural knowledge; through collaborative discourse personal understanding may become community knowledge; and community knowledge will come back to enrich individual understanding.

Scardamalia and Bereiter (2006) pointed out that the interaction among the individual understanding and community knowledge is embodied by the knowledge building discourse. What defines knowledge building discourse is not the form of the discourse; it can be online discussion, face-to-face discussion, or in other forms. It is a set of commitments that distinguish knowledge building discourse from others: (1) a commitment to progress; (2) a commitment to seek common understanding rather than merely agreement; (3) and a commitment to expand the base of accepted facts (Scardamalia & Bereiter, 2006).

In conclusion, knowledge building is a process that produces community’s collective knowledge. The collective knowledge does not reside solely in individual minds, but is created as authentic ideas, sustained in unfolding process, advanced through emergent collaboration, and developed through metacognitive discourse. The community members take the epistemic agency and collaborative responsibility to set up learning goals, expand on ideas, reflect on knowledge building progress and make plans for future inquiry. In this case,
all the pedagogical designs, including the assessment designs for knowledge building progress should capture the specific nature of knowledge building and respond to the needs for its advancement. These needs include individual and community cognitive advancement, and the development of social dynamics in the knowledge building discourse.

**Assessment of and for Knowledge Building**

In this section, the literature of assessment in current knowledge building practice is reviewed. First investigated is the changing of assessment paradigm, and then current literature of formative assessment is reviewed. Second introduced is the research that characterizes the essential aspects of the knowledge building in the assessments. Third the gaps and challenges are brought out based on the review result. Finally a possible assessment design and research questions for current study are proposed.

**Assessment paradigm for different learning theories.** Historically speaking, the purpose, focus and methods of an assessment design are influenced by the evolution of learning theories. How people define knowledge will determine how learning is perceived, what performance is presumed as knowing, and which achievements should be evaluated and how they should be assessed (Shepard, 2000).

For example, behaviorism (Hull 1943; Skinner, 1938, 1954; Gagne, 1965) conceived of knowledge as hierarchically organized associations that present an accurate but incomplete representation of the world. Behaviorists defined learning as accumulation of stimulus-response associations; a learner that demonstrates accurate knowledge components
is presumed as knowing. Based on these notions the focus of assessment was defined as the mastery level of the knowledge components (how many and how fluent), and accordingly the best assessment methods were standardized tests based on psychometrics.

Likewise, cognitive constructivism (Piaget, 1977) sees the nature of knowledge as conceptual structures that are constructed by the mind and according to rational criteria. Knowledge is represented by the ability to apply existing structure to new experience and rationalize it. The assessment thus needs to evaluate the learners’ extended performance on new problems.

Social-culturism (Vygostky, 1978) perceives knowledge as a representation for the culture of community which continues to create it. To know not only means the development of intelligence, expertise in academic disciplines, meta-cognitive skills, and the formation of identity, but also means to be attuned to the constraints and affordances of systems in which activity occurs. Assessment, in turn, should capture both the individual’s participation and achievement in inquiry and social practices.

Social constructivism views knowledge as a socially mediated product (Stahl, 2000). Learning is a group of learners with different cultural backgrounds and values negotiating a solution to an identified problem, and the group themselves will have to determine what factors of the problem should be focused and emphasize it in solving a defined problem. In this case learning is a dynamic, on-going, and evolving result of complex interactions, and new sub-goals are continually identified in the meaning making process.
(Stahl, 2004). The assessment to the socially constructed knowledge thus should emphasize the students’ active engagement with every stage of the assessment process so that they fully understand the requirements of the process, especially with the assessment criteria and with the assessment feedback (Rust, Price & O’Donovan, 2005).

As the important sub-field of social constructivism, knowledge building theory also defines knowledge as community property rather than merely individual mental content. Knowledge is represented by conceptual artifacts which are collectively developed by community members. Knowledge building is considered as a community endeavor which focuses on advancing the community’s knowledge that has an out-in-the-world existence, with individual learning as an important and demonstrable by-product (Scardamalia, Bereiter, & Lamon, 1994). To know is the interaction between the individual cognition and collective knowledge as well as metacognitive discourse among the community members. Such interactions among a network of people and ideas lead to not only information sharing but transformation and creation of knowledge (Paavola & Hakkarainen, 2005). Scardamalia et al. (2012) argue that the assessment for knowledge building should be concurrent, embedded, and transformative. Concurrent assessment means that the assessment is instantaneously available; embedded means the assessment is part of the day-to-day knowledge building practice; and transformative means the assessment is not only an account of past performance and pointing to immediate next steps, but also a method for individuals and teams to tackle broader problems and situate their work in relation to other people with or outside their classrooms. These descriptions emphasize that the assessment for knowledge building should
provide instant feedback for idea improvement since it is a sustained progress; it should also inform deeper and broader inquiry via next steps.

**Current assessment practice of and for knowledge building.** van Atlast and Chan (2007) argued that the assessment should played dual roles in knowledge building practice: it should both of knowledge building (measuring the advancement) and for knowledge building (scaffold the development). This argument has many aspects in line with formative assessment. For example, a frequently cited definition of formative assessment is:

Practice in a classroom is formative to the extent that evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited (Black & Wiliam, 2009, p. 6).

The essence of formative assessment, as Andrade (2010) pointed out, is “informed action,” which indicates the importance of feedback and a response to that feedback (p. 345). Wiliam and Thompson (2007) also proposed that three processes were central to build a formative assessment: (1) establishing where learners are in their learning; (2) establishing where they are going; (3) and establishing how to get there. They highlighted the fact that the function of formative assessment is not limited to the dimension of informing instruction and learning, but extended to serving as an integral part of the learning process. The students achieved deeper understanding to their previous learning as well as higher level cognitive skills through metacognitive activities. These ideas echo the proposition of knowledge building theory which considers knowledge building practice as a continual improvement of
conceptual artifacts, thus needs assessments to provide information for improving future inquiry, not just make judgment of previous learning and instruction.

Wiliam and Thompson (2007) pointed out that in formative assessments, the goals for learning and criteria for success should be understood by the learners, the feedback should be provided to the learners to move their learning forward, and students should be involved both as the owners of learning and the learning resources for one another. Cizek (2010) also advocated that formative assessment highlights the notions of student engagement and responsibility for learning, student self-assessment, and self-direction. This is in line with the knowledge building principle that students should have epistemic agency and collective responsibility to the knowledge building processes that continually create and forward conceptual artifacts.

These overlapping ideas between formative assessment and knowledge building make formative assessment an important assessment method in knowledge building research. Scardamalia et al. (2012) claimed that it is essential to make the assessment for knowledge building formative in order to support community knowledge and group intelligence. Some assessment practices has been conducted to measure and foster knowledge building, including capturing and fostering the advancement of three major attributes of the knowledge building practice: community knowledge advancement; community’s social dynamic change; and the development of individual understanding. (Zhang & Chen, 2012).
Assessment of and for community knowledge advancement. Community knowledge advancement refers to the development of the community’s conceptual artifacts, and is a sustained collaborative effort of the whole community which cannot be measured through calculating average, overlapping, or adding up individual’s performance (Berieter, 2002; Stahl, 2006). It needs different methodologies to capture the information about group interactions and group knowledge advancement. Stahl, Koschmann, and Suthers (2006) advocated that since the group members construct the community knowledge through displaying utterances, texts, diagrams and other artifacts in a shared public space, by capturing adequate record of these displays, the collaborative process can be reconstructed and interpreted.

Based on this statement, some qualitative data analysis methods such as discourse analysis and video analysis were employed to characterize the community advancement in the knowledge building discourse (e.g., Guzdial & Turns, 2000; Hewitt, Brett, & Peters, 2007; Hewitt & Teplovs, 1999; Hmelo-Silver, 2003; Hong & Scardamalia, 2008; Howell-Richardson & Mellar, 1996; Koschmann, Stahl, & Zemel, 2006; Sacks, 1992; ten Have, 1999; Teplovs & Fujita, 2009;; Weinberger & Fischer, 2006). Due to the integrated nature of knowledge building with the online learning systems, some technological tools have been developed and utilized to capture the continually evolving community knowledge. For example, Knowledge Forum (KF) provided third-party developed Java based analysis tools embedded on KF, such as semantic analysis tools, and vocabulary growth analysis tools. These tools have been
utilized to support the researchers to retrieve and analyze the online discussion data. For instance, Sun, Zhang & Scardamalia (2011) used the vocabulary growth analysis tool to track the occurrences of epistemic words and domain-specific terms in online written discourse. Some researchers retrieve the data from KF and develop their own tools to analyze the data. For example, Teplovs and Fujita (2009) created a semantic analysis tool to analyze students’ participation patterns and online interactions based on extracted and clustered key terms from students’ online discourse.

These analysis methods and tools provide many choices on the methods of evaluating the quality of community knowledge advancement. However, most of the analysis methods and tools were either too complicated or time consuming to implement in the everyday classroom. The information generated by these tools is also difficult to interpret even to the teachers, not to mention the students. This relegates most of them to research instruments that only serve researchers’ needs on assessing the achievements of the community knowledge. The students’ roles in these analysis activities were the objects of analysis, and the results of the analysis usually were not sent back to the students. In other words, the feedback was mostly sent to the researchers instead of the teachers or students, thus it was not used as scaffolds to inform next step teaching or learning. As Van Aalst and Chan (2007) stated, the potential of technology tools embedded in CSCL environments to scaffold learning remains underutilized.
van Aalst and Chan’s (2007) proposed that students should have a more important role in assessing their own community knowledge. They addressed this issue by engaging students to work as active examiners of their learning and take the responsibility to synthesize the community’s knowledge building progress. Through writing reflective texts in their portfolio notes, the students characterize the growth and development of individual and collective knowledge advances over time. A set of knowledge building principles to guide the reflection: (1) working at the cutting edge; (2) Progressive problem solving; (3) collaborative effort; (4) Identifying high points. Compared with traditional assessment through creating portfolio, in this study the students’ attention shifted from their individual achievement only to the advancement of the whole community. Suthers, Vatrapu, Medina, Joseph, and Dwyer (2008) students to collectively created evidential maps to synthesize and review theories and evidence that contributed to their argumentative discourse. The evidential maps served as collaborative “representation guidance” (representational support for the conceptual structure of a problem) to foster reflective and coherent conversations. This study is also a valuable attempt to involving students to reflect and synthesize their contributions in the online discourse through creating evidential maps. Compare with Van Aalst & Chan’s (2007) work within which students did the assessment individually, Suthers et al.’s (2008) research is one step forward in making assessment a collaborative effort since all the students contributed to the same evidential map. The
drawback for this research is that these concept maps could soon become too large or too complicated within a big group or over an extended period of time.

Some other researchers tried to create assessment tools especially designed for supporting students’ involvement in assessment activities. For instance, van Aalst et al. (2012) developed Knowledge Connections Analyzer (KCA), an SQL-based formative assessment system to support the students to reflect on their online discourse on KF based on four general questions: (1) Are we collaborating? (2) Are we putting our knowledge together? (3) How do ideas develop over time? (4) And what is happening to my stuff? Through answering these questions the students measured the achievements of their community knowledge. However, how the students use this information as the feedback to foster their future inquiry was not discussed.

Chen, Zhang, and Lee (2013) developed a timeline-based collective discourse mapping tool: the Idea Thread Mapper (ITM). ITM Interoperates with Knowledge Forum (Scardamalia & Bereiter, 2006) and potentially other collaborative learning platforms. Beyond the micro-level representations of ideas as postings and build-on trees on KF, ITM incorporates conceptual threads of inquiry -“idea threads” (Zhang et al., 2007) - as a larger, emergent unit of ideas in online discourse (See Figure 2.3). The progress in each idea thread is further made transparent by students through co-authoring a “Journey of Thinking” synthesis. Idea threads and thread-based syntheses are co-editable by members of the community, with each version recorded for later review. The community knowledge of the community in a whole inquiry is further represented as an idea thread map, a cluster of idea
threads that address interrelated problems.

Figure 2.3. An example of an idea thread created by young students through ITM tool (Chen et al., 2013).

ITM could provide representation guidance of collaborative inquiry in the form of charts, graphs, and mapping. And the use of these tools, as Chen et. al’s (2013) study suggested, could increase the students’ awareness of community knowledge and inform their collaborative efforts on the future inquiry. These tools could also be used to scaffold metacognition discourse among the community members to achieve agreements with the community knowledge and make plans for deeper inquiry (Zhang et al., 2013). This means that this tool could facilitate the students to assess their community knowledge, and use the feedback to inform their future inquiry.
Assessment of and for social dynamic change. Social dynamic change refers to the change of community’s social interaction structure. It reflects individuals’ social status in the network and the patterns of interaction among members in the community (Shen, Nuankhieo, & Huang, 2008). In knowledge building practice, community knowledge is developed through social interaction among the members, and individual cognition is advanced through the interaction with group cognition (Zhang et al., 2009). The characteristics of the interaction structure (such as how actively and cohesively individual students are sharing and building on one another’s ideas) will greatly impact information exchange between the community and the individual.

Knowledge Forum (KF) provided technological tools to capture the social dynamics change of the community. For example, an Automatic Tool Kit (ATK) (http://analysis.ikit.org) for the researchers to retrieve quantitative measures to analyze students’ social actions on KF, including: the numbers of notes created and read; the number of notes with scaffolds or keywords; and who has read or responded to the notes written by each student (interactional data). There is also a social network analysis tool embedded on KF, with which the users can find out the network density, individual’s social position, and community’s engagement distribution on certain discussion topics. Through analyzing these measures in social network analyzing tools (such as Netminer 4.0), the researchers traced the social dynamic changes in the community along with the time (de Laat, Lally, Lipponen, & Simons, 2007; Guzdial & Turns, 2000; Hewitt & Teplovs, 1999; Hewitt, Brett, & Peters, 2007; Howell- Richardson & Mellar, 1996; Zhang et al., 2009).
Similar to the assessment methods for community knowledge, most of the assessment methods for social dynamics change only serve researchers’ needs; very few have been integrated in everyday classroom life to assess and scaffold collaborative knowledge building. However, Baker-Doyle and Yoon’s (2011) study proved that the social network analysis tool which was embedded in Knowledge Forum could be interpreted and utilized by the students. In this study, automatically generated social network graphs were provided to the students, and they can choose their partners in the future paired-discussions based on the information they get from the graphs. The result shows that with the support of the social network graph, the students’ decision making mechanism about whom to interact with shifted from non-reflective or socially driven to information driven.

**Assessment of and for individual understanding development.** The individual understanding development refers to the change of students’ personal knowledge constructs, mainly focuses on the deep understanding that each student gains from the interaction with group cognition and the awareness of how to better contribute to the community (Zhang et al., 2007). As discussed before individual understanding is the starting and ending point of social knowledge building, thus the quality of individual understanding will both be the cause and the result of the group cognition development (Stahl, 2006). To capture the growth of individual understanding in the knowledge building, some researchers borrowed traditional assessment tools, such as standardized tests to assess individual learning outcomes based on pre-defined learning objectives and curriculum standards. For instance, Sun, Zhang, and Scardamalia (2008) collected students’ scores on the Canadian Test of
Basic Skills (CTBS) at the end of Grade 4 to analyze how their scores on literacy-related subtests (i.e., spelling, vocabulary and reading comprehension) were correlated to their lexical frequency profiles. Zhang et al. (2009) evaluated individual students’ knowledge gains through having students complete pre- and post- tests and analyze students’ individual portfolio notes. Some other researchers employed content analysis to categorize peer responses, types of questions asked, depth of ideas generated, evidence use, argumentation patterns, and sustained input to addressing core problems in students’ individual work (e.g., Hakkarainen, 2003; Hmelo-Silver, 2003; van Aalst & Chan, 2007; Weinberger & Fischer, 2006; Zhang et al., 2007).

In van Aalst and Chan (2007)’s study, the students reflected on how their individual understandings progressed in the collaborative knowledge building in their portfolio notes: how other student’s ideas changed their original thoughts, and how the discussions brought their “Aha” moments. This was an example of how the students played active roles in the assessment of their individual understanding. However, although the authors argued the assessment were “formative assessment”, the students did not compare their achievements and goals, and the feedback is not explicitly generated to inform their future learning.

In sum initial efforts have been made to develop analysis measures for knowledge building (Suthers et al, 2008; Van Aalst & Chan, 2007; Zhang et al., 2009). However, there are still gaps between the current assessment practice and the need of collaborative assessment. Knowledge building theory emphasizes students’ epistemic agency and
collective responsibility in the sustained knowledge advancement process (Scardamalia & Bereiter, 2006). Students should have some control with what should be assessed, how the achievement should be measured, and what should be done after the assessment.

Nevertheless, the above literature suggested that the majority research for the assessment still focused on external analysis to the community knowledge, social dynamics, and individual understanding. Many knowledge building researchers advocated that the analysis tools could be used by the knowledge building community in formative assessments, but most of these tools remain as researchers’ instruments instead of students’ tools. Students tended to be the objects of the external assessment instead of active agents of the internal assessments. Some studies attempted to engage students as active agents in the assessment activities, but the assessment activities are still individual act instead of collective efforts.

Gaps also exist between the formative literature and knowledge building theories. Current literature of formative assessment usually focused on individual achievements, and rarely takes community knowledge and social dynamics as assessment focus. The formative assessment literature rarely discussed the interactions between the individual cognition and group cognition, or between the social dynamic change and the community knowledge. Some current formative assessment literature emphasizes students’ active roles in the assessment process, and they advocated that the students should take certain responsibilities in the assessment activities through self-assessment and peer assessment (Andrade, 2010; Ruiz-Primo & Li, 2013). However, in most of the studies it was still the teachers decided the assessment activities and procedures, and the feedback was usually used by the teachers to
improve their instructions (Black & Wiliam, 2009). How the students could work with the teachers as a community to manage the goals, process and outcomes of the assessment, and used the feedback to inform the future community knowledge advancement needs further investigation.

Moreover, most of the practices focused on “assessment of” the existing achievements, and the “assessment for” next step inquiry was often neglected. The assessment results stopped at characterizing the existing achievements, and rarely been provided to the students as the feedback to inform their next step inquiry. Some assessment designs try to provide feedback on some aspects of inquiry, but none of them managed to address all the essential aspects of knowledge building practice. Most of the assessment only focused on one aspect of the three major attributes of knowledge building: they focused either on community knowledge, individual understanding, or social dynamics. Systematic design and implementation that addressed all these three attributes were rarely found in the literature about assessment for knowledge building.

Assessment Design Frameworks. Messick (1994) advocated that assessment should be an evidentiary structure that connects all the assessment elements with logic. Usually it is a process of reasoning from limited evidence of what students say, do, and make in particular settings, to claims about what they know and can do more broadly. He laid out the general reasoning chain that an assessment design should follow:

A construct-centered approach would begin by asking what complex of knowledge, skills, or other attributes should be assessed, presumably because they are tied to explicit or implicit objectives of instruction or are otherwise valued by society.
Next, what behaviors or performances should reveal those constructs, and what tasks or situations should elicit those behaviors? Thus, the nature of the construct guides the selection or construction of relevant tasks as well as the rational development of construct-based scoring criteria and rubrics (p. 16).

To make the structure of an assessment more explicit, Haertel et al. (2012) proposed an Evidence-Centered Design framework (ECD) (See Figure 2.4). This ECD framework invokes the layers metaphor in its approach to assessment, which is drawn from architecture and software engineering.

![Figure 2.4. Graphic Representation of ECD Layers (Haertel et al., 2012)](image)

The ECD framework provides detailed explication of the reasoning behind assessment design decisions. It emphasized how each element logically connected to each
other: from the top down the assessment argument evolves from a general substantive one to an increasingly specific one; and the content and purpose of the assessment are being increasingly refined. It is argued that if systematically implemented, ECD may increase the content validity of the assessment design since it may build solid reasoning chain between the assessment practice and assessment argument (Mislevy, Almond, & Lukas, 2003).

ECD framework works very well with the standard test, but it cannot be directly applied to formative assessment since emphasizes the objectivity on task design, assessment delivery and scoring. In other words, the assessments need to be designed, delivered, and scored by the teachers or third parties. However, in knowledge building practice, the students are the ones who determine the breadth and diversity of their inquiry, and there could be no “external” people to implement or deliver assessment. The students are the ones who gather and analyze the evidence of group advancement and individual development, generate evaluations to the group work as feedback to each individual, and administrate the collaborative process. In this case, the valuable part of ECD to the assessment for knowledge building is that it suggested when designing an assessment, a reasoning chain needs to build among the assessment activities.

Compare with ECD framework, the framework of formative assessment emphasized students’ active roles in the assessment activities. For instance, Black and Wiliam (2009) proposed that generally formative assessment should have five key activities:

1. Clarifying and sharing learning intentions and criteria for success;
2. Engineering effective classroom discussions and other learning tasks that elicit evidence of students understanding;
3. Provide feedback that moves learners forward;
4. Activating students as instructional resources for one another;
5. Activating students as the owners of their own learning. (p. 8)

These assessment activities need three major agents (teacher, peer, and learner) to go through three key processes of assessment (where the learner is going, where the learner is right now, and how to get there.) To reveal how each part of the assessment (the major processes, key activities, and involved agents) work together, Wiliam and Thompson (2007) proposed a framework for formative assessment as following:

<table>
<thead>
<tr>
<th></th>
<th>Where the learner is going</th>
<th>Where the learner is right now</th>
<th>How to get there</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Teacher</strong></td>
<td>Clarifying learning intentions and sharing and criteria for success (1)</td>
<td>Engineering effective classroom discussions, activities and tasks that elicit evidence of learning (2)</td>
<td>Providing feedback that moves learners forward (3)</td>
</tr>
<tr>
<td><strong>Peer</strong></td>
<td>Understanding and sharing learning intentions and criteria for success (1)</td>
<td></td>
<td>Activating students as instructional resources for one another (4)</td>
</tr>
<tr>
<td><strong>Learner</strong></td>
<td>Understanding learning intentions and criteria for success (1)</td>
<td></td>
<td>Activating students as the owners of their own learning (5)</td>
</tr>
</tbody>
</table>

*Figure 2.5 A framework of formative assessment (Wiliam & Thompson, 2007)*

It suggests that to establish where the learning is going, the goals and the criteria for success first need to be understood by all the agents. Then the evidence of students’ achievements needs to be collected to establish where the learners are in the moment. After that, feedback needs to be generated based on the evidence to determine how to achieve the initial goals. It emphasized that the students need to be activated as the owner of their learning as well as the resources for each other. Students are centrally involved in each step.
Ruiz-Primo and Li (2013) further developed this framework in their study. They added “evidence interpreting” after “evidence collecting” in the “where are we?” step. Evidence interpretation is a process of inferring the current knowledge status based on the collected evidence, and identifying any gaps between the current status and the learning goals. Adding this step emphasized the comparing of the goals and students’ synthesized understanding to their current achievements. This framework also encourages the assessment designers to consider the social structures that influence the teachers’ and students’ roles, the enabling tools that support and mediate students’ thinking, the sequence and frequency of the assessment activities, and the importance to check the connection between the assessments with students’ after-assessment performance.

The frameworks of formative assessment could be very useful on designing assessment for knowledge building. They focused on collecting and interpreting assessment information, and offering feedback to move the learning forward. This is the basic purpose of the assessment for knowledge building. They also recognized the important roles of the students in the assessment processes, and this echoes with student’s epistemic agency in knowledge building practice. The activity cycle defined by these two frameworks (especially Ruiz-Primo and Li’s (2013) activity cycle) also fits the need of continually evolving idea development in knowledge building.

Gaps still exists between these frameworks and the need of assessment of and for knowledge building. The goals of the learning are pre-defined by the teachers instead of defined by the community, and these goals remain the same after the assessment activities
instead of changing along with the idea development progress. Ruiz-Primo and Li’s (2013) framework emphasized students’ social participation, but how the peers and students are activated as instructional resources and as the owner of the learning of the assessment was not clear. Moreover, both frameworks do not emphasize the interconnections among the activities. For instance, it did not raise questions like “what types of tasks should be used to collect the evidence?” or “how tightly the task are linked to the goals?” The inner logic that connects the assessment activities is not discussed.

The frameworks for formative assessment can be complemented by the evidentiary reasoning chain that emphasized by ECD framework. According to ECD, an assessment argument should start from setting the goals of learning, and then identifying the criteria that represent success in achieving the goals. The goals and criteria should determine what evidence needs to be collected, and how the evidence should be interpreted. The feedback based on the evidence should also closely link to the attainment of the learning goals, since the role of feedback lies in reduction of the gap between where the students are and where they plan to be (Ruiz-Primo & Li, 2013). The assessment of and for knowledge building should also build a reasoning chain between the assessment activities, and use the assessment frameworks for formative assessment as the reference to organize the major processes, key activities, and involved agents. Moreover, since the assumed reasoning chain is all based on assessment designers’ understanding of the knowledge building context, the validity of the assessment needs to be tested in the implementation of the assessment, and it should be revised based on the result from practice.
Implementing assessment in specific cultural contexts. Every community has its unique cultural background, and the implementation of assessment calls for deeper understanding of diverse cultural contexts (Scardamalia & Bereiter, 2006). As a term in educational setting learning culture is defined as following:

…it refers to historically-rooted cultural attributes related to learning and education carried by an identifiable community (e.g., a nation, a regional community, a school). These cultural attributes are demonstrated as collective, intuitive understanding of what learning is about and how it should be approached in practice, as well languages, signs, and social norms that mediate learning and teaching (Zhang, 2010, p.6).

In the current assessment literature the learning culture is usually being discussed in the framework of western schooling system. For instance, Shepard (2000) described the possible learning culture that is needed in the cognitive and constructivist assessment, and this learning culture is basically refers to the new conceptions and expectations in teachers and students’ mind toward knowledge. In other words, the author is talking about creating new learning culture for assessment in a specific context instead of adapting assessment in an existing learning culture. Most of researchers in schooling systems outside the US or Europe did not specify the cultural factors.

In specific learning culture the implementation may face different practical challenges and barriers. For instance, as Yin and Buck (2015) described, currently in most Chinese schools students are still passive knowledge consumers instead of active knowledge builders. Most of the classes in China are still teacher-dominated, and students rarely have the chances to express their opinions. Questions from the students, especially questions raised during teacher lecture, are often considered as impolite. To achieve high scores on the tests is the
ultimate goal to most of the students because the test scores will determine what type of high schools and colleges they can get in, thus impacting what type of jobs they can find after they graduate. Teachers are under pressure to help students achieve high scores in the standardized tests since students’ test performances may influence their salary. In this case, in most of the Chinese classrooms good memory is more valued than creativity; individual achievements are more rewarded than contributing to the collective good; and the extrinsic incentives (moving to a higher social status) are more important than intrinsic incentives (fulfilling individual potential) (Zhang, 2010). In this case, the implementation of assessment calls for deeper understanding of diverse cultural contexts (Scardamalia & Bereiter, 2006). Detailed description of the process of the implementation, including how it interacts with the local context as well as how the community members overcome the cultural barriers is highly needed.

Focus on This Research

The above literature reveals the need for new approach to the assessment that works for the special needs of the knowledge building practice. It needs to: capture community knowledge advancement, social dynamics change, and individual understanding development (Scardamalia et al, 2012; van Atlast & Chen, 2007; Zhang et al., 2007); provide ongoing feedback for the sustained idea improvement over relatively long periods (Zhang et al., 2009, Zhang et al., 2013); empower students to take epistemic agency and collective responsibility (van Atlast & Chan, 2007; Zhang et al., 2009); and make the assessment itself a collaborative effort to achieve agreement through metacognitive discourse (Chen et al., 2013; Zhang et al.,
2013). It should also provide an evidentiary reasoning chain that connects the assessment activities, thus building the content validity of the assessment (Scardamalia et al., 2012; Mislevy, et al., 2003).

The focus of this study is exploring new possibilities to serve these needs. To be specific, this study tried to bridge the knowledge building practice and formative assessment literature through designing formative assessment for knowledge building, and put this into specific context to get feedback from the community members. The design of the assessment should have following characteristics:

1. It should be embedded in the knowledge building process and provide concurrent feedback to inform the community’s continually sustained idea improvement the progressive deepening moves (Andrade, 2010; Black & Wiliam, 2009; Ruiz-Primo & Li, 2013; Scadamalia et al., 2010; Scadamalia & Bereiter, 2006; Zhang et al., 2009).

2. The assessment itself should be a part of knowledge building process which encourages all the community members' commitment to achieve consensus through metacognitive discourse (Zhang et al., 2009; Zhang et al., 2013).

3. It should utilize the technological affordance in the specific knowledge building environment to make the collaborative reflection and planning feasible and accessible to all the community members (van Atlast & Chen, 2007; Zhang et al., 2013).
4. It should provide an evidentiary reasoning chain that connects the assessment practice with the assessment argument, thus building the content validity of the assessment (Messick, 1994; Mislevy et al., 2003).

Moreover, the assessment design for knowledge building should also adopt the formative assessment activity cycle in Wiliam and Thompson’s (2007) framework and incorporate Ruiz-Primo and Li’s (2013) work to provide instant feedback to inform deeper and broader idea improvement. It should also borrow Mislevy et al. ’ (2003) idea of the reasoning chain to build the logic among the assessment activities. To be specific, a reasoning chain needs to be established to connect the assessment activities for “where the learners are going,” “where the learners are right now,” and “how to get there.” The reasoning chains for different attributes of knowledge building (community knowledge advancement, social dynamics, and individual understanding development) needs to be separately designed. The feedback that the students get from the assessments to three attributes should inform students’ next step knowledge building practice. These designs also need to put them into specific context to test their validity, and they also need to be revised based on the feedback from the community members. Details of the assessment design are illustrated below.

**Assessment Design for this Study**

Based on the above argument, this study proposed a design of the assessment of and for knowledge in a specific pedagogical environment with the support of technical tools.
Technology supported assessment tools used in current study. In this study Idea Thread Mapper (ITM) (Chen et al., 2013) and the social network tool embedded in Knowledge Forum was used as the technology tools to support the collaborative assessment (See Figure 2.6).

Figure 2.6 The major interface of ITM. (Zhang, Chen & Tao, 2014)
On the basis of Knowledge Forum data, the ITM tool supports user actions to generate idea threads, and an inquiry thread map for each inquiry-based learning project. To be more specific, through using ITM, the students can identify major themes from the ongoing online discourse (decide the names of idea threads), review questions and diverse contributions in each theme (create and edit the idea threads), and synthesize progress as well as challenges and controversies through writing “journey of thinking” posts. This “journey of thinking” text summarizes the development of each thread and highlights the next steps for further inquiry.) With the support of ITM, the students can also generate “idea thread maps” to provide a synthesized, high-level overview of the idea threads: how many idea threads are created? When was each thread started? How many notes were contributed to each thread over what time periods? How are the different threads connected through build-on links and common notes shared? Through interpreting an idea thread map, students can get an overview of their current inquiry status, and decide the focus for their future inquiry (Chen, et al., 2013; Zhang et al., 2013).

The social network tool embedded in Knowledge Forum provides basic social network data and graphs that help the students to understand the interaction of the community. For instance, the circle graph shows how each person is connected to different peers. As shown in Figure 2.7, each node represents one student in the community, and the size of the dot indicate the activeness of the student in this community (the bigger the dot is, the more active the student is interacting with others). When clicking on one dot, the red lines show how the build-on connections this student sent to and received from other people. Figure 2.8
shows spring graph that indicates the engagement of the participants in the community. Each dot represents a student’s social position in the community. The more centralized a dot is, the more active the student is interacting with other people. The dots that are far from the middle or isolated represent the students who are less engaged in the group discussion. Through interpreting the circle graph, the students can see how dense the community members are connected to each other; and through looking at the spring graph they could see how the engagement is distributed.

Figure 2.7. A circle graph of build-on notes. It shows how dense the community members are interacting with each other. Each line represents an interaction between one student and another. The size of the dot represents the activeness of one student in the interaction.
Figure 2.8. A spring graph of build-on notes. Each line shows an interaction between students. The more engaged students were shown closer to the center of the graph.

Assessment design of and for three major attributes. The assessment design for this study adopts the basic assessment activities in Ruiz-Primo and Li’s (2013)’s framework. This includes clarifying learning goals, collecting/eliciting evidences, interpreting the evidences, and using feedback to adjust the future inquiry. The assessment design also borrows from Mislevy et al.’ (2003) idea of the reasoning chain to build the logic from the goal to the feedback. To establish “where the learners are going”, the community first needs to set up the learning goals and success criteria. Then to establish “where the learners are right now”, the community needs to collect evidence that reflects their progress toward the
goals, and then generate feedback based on the interpretation of the evidence. After that, the community needs to decide “how to get there”, and use the feedback to suggest ways to improve future inquiry.

As discussed before, three attributes are valued in knowledge building practice: community knowledge advancement, social dynamics, and individual understanding development. Table 2.1 describes how the reasoning chain is constructed for each valued attribute from the goal to the criteria, evidence that is elicited by the tasks, and feedback obtained to inform future learning.

Table 2.1.

*The Designs of Assessment of and for Knowledge Building*

<table>
<thead>
<tr>
<th>Community knowledge</th>
<th>Where are we going?</th>
<th>Where are we now?</th>
<th>How to get there?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clarifying learning intentions and criteria for success</td>
<td>Eliciting evidence for achievement</td>
<td>Interpreting evidence</td>
</tr>
</tbody>
</table>

<p>|                      | Collaboratively define the goals emerging from the knowledge building practice | Collaboratively create idea threads, idea thread maps and “Journey of Thinking” syntheses to represent the theme | Collaboratively interpret “idea threads,” “idea thread maps” to find out the theme coverage and idea progress; Find out the | Collaboratively making plans for addressing the gaps between the current knowledge and final goals as well as |</p>
<table>
<thead>
<tr>
<th>Social dynamics changes</th>
<th>Collaboratively define the goal of social dynamic change as high degree of participation and distributed engagement</th>
<th>The SNA tools automatically collect the social network data and generate SNA charts</th>
<th>Interpret the network density, community’s distribution of engagement, and individual’s social position based on SNA charts</th>
<th>Collaboratively make plans for improving the network density and distribution of the engagement in next step inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of individual understanding</td>
<td>Individually define the emergent goals of personal understanding and the connections between personal understanding and community knowledge</td>
<td>Individually write portfolio notes to reflect on the individual understanding developments and the connections between the individual and community knowledge advancement</td>
<td>Individually find out the progress and challenges in personal understanding development</td>
<td>Individually make plans to indicate their potential contributions to the community in the next step inquiry</td>
</tr>
</tbody>
</table>
Assessment design of and for community knowledge advancement. The goal of the community knowledge advancement, as discussed before, should be defined by the community members (both teachers and students) instead of imposed by the teacher or third party. They need to decide what topics they want to explore, and how deep they want to go with these topics. The indicators of community knowledge advancement, as Zhang et al. (2012) advocated, refers to the conceptual landscape of the community members' collective work (how many themes are discussed and how they are connected), and the sustaining progress of an idea improvement (how each idea is developed and how deep the ideas have gone). To elicit the evidence of these indicators, the students collaboratively produce a series of conceptual artifacts with the support of the ITM tool, including: (1) “idea threads” to trace the trajectory of idea development of certain topics in their science; (2) “idea thread maps” to lay out the important themes of inquiry explored; and (3) “journey of thinking” posts to identify the gaps and challenges for future learning and to generate plans for future inquiry on a certain theme. The designing of these tasks are based on the argument that the idea threads could represent the idea development trajectory in the knowledge building practice (Zhang et al., 2007). The structure of an idea thread could provide a detailed account of the trajectory of an idea development, which shows the depth of the communal work on this specific topic. A “Journey of Thinking” post could also provide a scaffold for the students to reflect on the cognition progress in the discussions about this theme (Zhang et al., 2012).
The idea thread map could provide a graphic view of the scope of the knowledge building in a certain period of time (Zhang et al., 2012). Based on interpretations of the idea thread map, the students could collaboratively identify the gaps in and challenges to current learning, and set up foci for future inquiry (e.g. what are the gaps in and challenges of the current inquiry? What theme needs further investigation? What themes need to be strengthened? What deep questions have not yet been asked? What theme needs to be new foci of future inquiry? What are the connections among the ideas?)

The feedback that the students could generate based on the interpretation of the evidence includes detailed, in-depth understanding of idea coverage and the trajectory of each idea thread, and the knowledge of the idea progress, as well as the gaps and challenges of the current collective achievement. This was the basis for the community to make plans about what needed to be done to fill the gaps between the current knowledge and the shared goals of the community.

Assessment design of and for social dynamics change. In a well-functioning knowledge building community, members should actively participate in the discussion, thus there should be frequent and close interaction among the participants (Zhang et al., 2009). The engagement of the participants should also be distributed instead of focusing on a few people. This goal needs to be shared by the whole community, and the change of the social dynamics should be indicated by the interaction patterns of the community (Zhang et al, 2007).
To understand the social dynamic change of the community, the students worked with the teacher to reflect on their degree of participation and engagement distribution with the Social Network Analysis (SNA) tool that is embedded in the Knowledge Forum. Two SNA graphs (circle graph and spring graph) provided a quantitative and graphical overview of the community’s social dynamic. The teachers and the students reflected on their social behaviors in terms of following aspects: (1) Where am I in the social network chart? (2) How frequent are the community members connecting to each other on the circle graph? and (3) Are we having more students staying at the edge of the spring graph, or in the center of the graph?

The feedback that the students could get from assessing the community’s social dynamics includes understanding their community’s interaction patterns, their individual social positions in the community, and the knowledge about the challenges of their current community’s social network status. The students also discussed about the possible directions and methods to improve the community’s social dynamics.

Assessment design of and for individual cognition development. The goal of individual understanding development should also be defined by the students. However, the unfolded and emergent nature of the idea development in knowledge building could make it hard for the individual students to determine the breadth and depth of their understanding development in advance. In this case, the goal of individual understanding development focused on “change” (how much the understanding developed in the knowledge building practice) and “connection” (how the individual understanding connects to the community
knowledge). To elicit the evidence on these two aspects, the students wrote individual reflection notes about their personal knowledge gain from the knowledge building practice. They reflected how their personal understanding grow with the community knowledge advancement (What new ideas have I learned? What notes/threads brings out the “Aha” moment to me? How did my initial ideas interact with the group discussion and become better ideas?). Based on these reflections, the students generate their interpretation to the status of current individual cognition development, including the understanding of what individual progress they had made in the previous knowledge building, and what challenges are in their personal understanding development. Based on these interpretations, students made plans about their personal actions to connect their personal cognitive need and interest with the community’s inquiry advancement need for future inquiry (What contribution can I make to the community in the future? What gaps/challenges should I address in the future? What can I do to help others’ learning?).

**Implementation procedures.** The collaborative assessment in this study is a combination of face-to-face discussion and online discourse. It is also a synthesis of individual work, small group effort and whole class collaboration. Many collaborative efforts (including identifying themes, generating and constructing idea threads, interpreting threads and maps, and planning future inquiry) are needed in the assessment activities. These collaborative assessment activities not only need the individual contributions and social interactions, but also need the support of the technology tools.
To address the above demands, the implementation of initial assessment design in this study was planned as followed:

1. Collaborative knowledge building on Knowledge Forum (2 weeks, 8 class hours).
   The knowledge building process of one inquiry topic usually lasted for four to five weeks. With the support of Knowledge Forum (KF), the students started their knowledge building practice from a general exploration of science topics on their textbooks. The students articulated questions and ideas they had about the topic and discussed the general goal of what they attempted to accomplish. After that, students collaboratively and progressively explored the problems the class had formulated. They contributed their ideas to KF and built on each other’s notes to advance their knowledge. Students engaged in discussing the topics that they were interested in and formed discussion groups.

2. First formative assessment session (four class hours). After two weeks of discussion, with guidance from the teacher, the students participated in an "ITM session". The ITM session usually lasted for three class hours.
   During the first ITM session, with the support of the technical tools, the students worked with the teachers to assess their collective knowledge, social dynamics and individual achievements, and then made plans to inform their next step inquiry.
3. Continue collaborative knowledge building on Knowledge Forum for the same topic (2 weeks, 8 class hours). After the first ITM session, the students continued their knowledge building practice and used what they learned in first ITM session to inform their deeper efforts. This after-assessment discussion lasted for another 2 weeks.

4. Revisit and update idea threads. On an ongoing basis, students updated the idea threads and the “Journey of Thinking” posts when they noticed new progress and challenges in certain threads. When the after-assessment discussion was completed, they engaged in another ITM session to reflect on progress in the existing threads and created new threads for new themes emerged from the discussion. Then they reflected on their achievements and challenges in their community knowledge advancement, social dynamic change, and individual understanding development.

5. Group presentation. The students worked as small groups to give the presentation about the thread progress to the class.

Research Questions

Based on this review of the literature, a formative assessment of and for collaborative knowledge building is designed and implemented, focusing on advancing productive, high quality knowledge building practice. The questions the research intended to illuminate are as follows:
1. How do students and teachers conduct the assessment of and for knowledge building?

2. Is the assessment of and for knowledge building associated with the advancement of the community's inquiry? If yes, in what ways?

2.1 Is the assessment of and for knowledge building associated with students’ collaborative deepening moves in their online discourse to advance their knowledge? If yes, in what ways?

2.2 Is the assessment associated with students’ individual understanding growth? If yes, in what ways?
Chapter 3: Methodology

This chapter introduces the methodology employed in this research. First introduced is the basic information of the research site, including the school and the participants. Second the research instruments are presented, which focused on the technology tools and assessment designs. Third introduced is the research design. Last data collection and data analysis methods are indicated.

Research Setting

This study was conducted at Zongbei Elementary School in Chengdu, China. During the summer of 2009, I was invited by a research institute in Chengdu to give a lecture about knowledge building theory and practice to a group of public elementary school principals. The principal of the Zongbei Elementary School was fascinated by the idea of knowledge building, and showed strong interest in participating in research related to knowledge building. Zongbei Elementary was then chosen as the research site for my pilot study conducted since the summer of 2011. The result of my pilot study shows positive association between students’ collaborative reflection and the structure of their social network as a knowledge building community, and it encouraged me to explore a comprehensive collaborative assessment design in a knowledge building community.

Zongbei Elementary School is located in Chengdu, a major city in southwest China. It is rated as one of the top five public schools in the Wuhou school district based on the students’ performances in the standardized tests of major subjects (Chinese and math). It also has a good reputation regarding its pioneering spirit of education reform; most of the teachers
are willing to try new instructional theories and methods. The community in which this school located is the downtown residential area for middle class families. There are over 2,000 students at this school, among which ten students from other countries (including the US, Pakistan and Korea). The technological facilities at this school are at the average level for the school district. This school has two campuses, each equipped with one computer room shared by over 1,000 students. Each computer room has fifty desktops connected to the Internet and a teacher-controlled broadcasting system. It is the major place for students’ Information and Communications Technology (ICT) class. In every classroom there is a desktop connected to the Internet, a 40-inch TV and an object projector. In each teacher’s office there are two desktops, and every teacher has one laptop. Wi-Fi signal covers the two campuses. Internet access can be found in every room at this school, but not every student can connect to the Internet all of the time.

As a Chinese elementary school, the context of Zongbei Elementary differs from US schools in following major aspects:

1. School organization. Instead of assigning one teacher to each classroom to teach all content subjects, each classroom at the Chinese elementary school classes has different teachers to teach different subjects, and one subject teacher may teach in multiple classrooms. In addition, the class size is much bigger, with 40 to 60 students in one classroom.

2. Standard and curriculum. In China there is one national standard for elementary science education released by the Ministry of Education of
Chinese government. It provides general guidelines about the goals of science education, the knowledge and skills that should be covered, and suggestions for inquiry activities and assessments. However, there are no specific contents and activity suggestions for each grade (sample curriculum can be found in Appendix C). It is the textbook authors’ responsibility to create the curricula based on the standard, and make sure the standard is represented by the contents and activities in the books. To most of the Chinese science teachers, they do not worry too much about the standard or curriculum. What they need to do is follow the textbooks and make sure all the contents in the books are covered.

In the above school context, I choose to focus on science teaching instead of other subjects based on a number of considerations: (a) Science is a marginalized subject in Chinese elementary schools. It is not considered to be a “must excel” subject because school evaluation focuses on testing students’ performances in mathematics and Chinese in every semester. This lessens the school administrators’ and teachers’ stress in science teaching, making it possible for teachers to try new teaching methods; (b) Science is characterized by the construction of ever-deeper explanations of the natural world and therefore is considered as a creative, idea-driven enterprise instead of a collection of evidence and facts (Chuy et al., 2010). Lederman (1999) also identifies “creativity” and “socially, culturally embedded” as important aspects of the nature of science. This belief about the nature of science is in line with the focus of knowledge building on sustainable idea creation and improvements. Science
classrooms thus become the major research setting of knowledge building studies (Suthers et al., 2008; Van Aalst & Chan, 2007; Zhang et al., 2007); (c) The abundance of the pedagogical designs in knowledge building practice in the literature also provide examples and support to the Chinese science teachers.

Participants

The participants of this study include two teachers and 79 students. They are all active agents in the collaborative assessment activities. Details about these participants are described below.

The teachers. Two teachers - one science teacher and one ICT teacher - are involved in this research. Ms. Lee, the science teacher, has eight years of teaching experience. She has a good reputation regarding her teaching quality among her colleagues. Although she has been very proficient with traditional instructional practice, she does not want to stay in her comfort zone. She is willing to try out new theories and practices. Ms. Yong, the ICT teacher, is a novice teacher who had graduated from college for one year before she participated in the pilot study. She is a fast learner of new technologies, new teaching theories and new methods, but lacked experience with implementing educational theories into practice. Both of them are willing to take the challenge, and they consider participation in this research project as an opportunity for their professional development.

Although the teachers each have the passion and determination to conduct knowledge building in their classrooms, they have barriers to overcome. First, it is the first time they have worked as participants in an educational research project. They have to learn
how to collaborate with the researcher and find their roles in the research practice. Second, knowledge building is a new theory to them, thus they have to change their existing epistemology to accommodate it. Third, they have never tried using an online learning interface like Knowledge Forum in their teaching practice; therefore it was very challenging for them to utilize its features in their teaching practice. Last, but not least, knowledge-building practice requests that the teachers build a totally different classroom culture and try new instructional activities, thus they have to be very creative and critical with their pedagogical design.

To help these teachers overcome these challenges, many small training courses have been provided to them since the pilot study began. In the summer of 2011, the training was focused on the theories of knowledge building and the features of Knowledge Forum. Beginning fall 2011, the teachers started to have weekly Skype meetings with the researcher, focused on implementing knowledge building theories into their teaching practice. They shared their teaching journals and classroom videos with the researcher, and discussed their questions and problems with their classroom teaching. After one and a half years practice in pilot study, the teachers are now familiar with the technical features of Knowledge Forum, and are feeling comfortable with the knowledge building practice.

The Students. Seventy-nine Grade 6 students from two classrooms participated in this study. They belong to two classrooms (Class A and Class B) and are the same ones who participated in the pilot study that was started in fall 2011. Class A has 39 students, and Class B has 40 students. Both classrooms have half male and half female students. There is no
ethnic diversity in these two classrooms. Although there is variation in social economic status (SES), most students come from middle class families; and this is typical for a public elementary school in a major Chinese city. Most of the students have computers and Internet access at home, but their parents generally do not allow them to spend a lot of time online. Most of the parents believe that their children are already spending too much time on their homework, and getting online might further impact their eyesight. In this study, students’ online work took place during their ICT classes.

The Chinese version of Knowledge Forum still has some English components. Most of the students have adequate English proficiency required to operate Knowledge Forum, and sufficient technology skills to use the Internet, search engines, picture editors and word processors.

Research Design

This study adopted a design-based research method to explore the assessment designs that can advance knowledge building practice in a specific cultural context. Design-based research – sometimes called “design experiment” – focused on developing educational designs based on principles derived from prior research and testing and refining the designs through a formative and iterative process (Collins, Joseph, & Bielaczyc, 2004). Collins et al. (2004) pointed out that design-based research works well under the following circumstances: a messy situation which characterizes real life settings (real education settings); a complex social situation where social interaction matters; and research that is aimed at developing quantitative and qualitative profiles to characterize a design in practice. Bereiter and
Scardamalia (2006) also pointed out that design-based research is a good choice for solving educational problems by developing effective innovations. This study attempts to develop a new assessment design for knowledge building practice that needs to be implemented and tested in a real educational setting where social interaction matters. In this case, design-based research method is an appropriate choice for this study.

This study adopted a two-phase, time-lag design (see Table 3.1). The students studied two scientific topics (energy and biodiversity), which came from their textbooks. Each inquiry lasted for approximately six to seven weeks. A technology supported assessment design was implemented in the students’ inquiry. The knowledge building community members (teachers and students) collaboratively collected and analyzed their inquiry process in a certain period of time, used the result to reflect on the challenges and gaps in their collective knowledge advancement, and made community and individual plan for deeper inquiry.

This assessment design was implemented in Class A in Phase 1 and then extended to both classes in Phase 2. The role of collaborative assessment in the knowledge building practice was examined by comparing Class A to B in phase 1, and comparing phase 2 to 1, especially for Class B. Design experiments do not usually require comparison or control classrooms as in conventional experiments (Reinking & Watkins, 2000). However, in order to clearly understand the role of collaborative assessment in knowledge advancement, a between-group comparison group is included in this study through the time-lag design. Students in class B were not in a “control” condition, but had the chance to use refined design
of collaborative assessment in Phase 2.

Table 3.1.

A Two-Phase, Time-Lag Design

<table>
<thead>
<tr>
<th>Condition</th>
<th>Pre-test 1</th>
<th>Phase 1 (Energy Unit)</th>
<th>Post-test 1</th>
<th>Pre-test 2</th>
<th>Phase 2 (Biodiversity Unit)</th>
<th>Post-test 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>X</td>
<td>Initial Formative Assessment</td>
<td>X</td>
<td>X</td>
<td>Refined Formative Assessment</td>
<td>X</td>
</tr>
<tr>
<td>B</td>
<td>X</td>
<td>Comparison</td>
<td>X</td>
<td>X</td>
<td>Refined Formative Assessment</td>
<td>X</td>
</tr>
</tbody>
</table>

According to Collins et al. (2004), a major characteristic of design experiment involves progressive refinement of design through iterative cycles over time. The data is not analyzed at the end of the experiment, but in regular, iterative cycles over the entire course of the research. In this study, the data was collected right after each ITM session and each phase. The assessment design was refined after Phase 1 based on the data analysis of how the community members co-participate in the collaborative assessment. As the co-designer of the collaborative assessment, the researcher closely collaborated with the participants to revise the collaborative assessment design. The improvement of the assessment design, including the task selection, the evidence design, and the implementation of the assessment, were based on the contributions from the teacher and students.

The validity of design-based research, based on Design-Based Research Collective (2003), can be achieved through the partnerships and iteration typical of design-based research, which results in increasing alignment of theory, design, practice, and measurement. In this study, the researcher was open to results from the cycles of data analysis, and the
contributions made by the teachers and students were accepted to better revise future intervention. One change that has been made is the adding of an authentic task as an additional evidence-collecting activity. To test what they can do with their collective knowledge about biodiversity, the students were required to collaboratively design an ecological balanced Moon Base for the human being. The other change in Phase 2 is that instead of merely looking at the SNA graphs, the teachers invited the students to interpret their social behaviors shown on idea thread map graphs on ITM (e.g. discussing why some posts concentrated in certain periods). This change was based on one teacher suggestion in the interview after Phase 1. She suggested that the assessment result to the social network change did not bring direct impact to most students’ social behaviors, and the social behaviors need to be connected to the cognitive actions to take effect.

**Data Sources**

There are six primary data sources for this study: students’ online entries on KF and ITM; social network data of online entries; class videos; class observations; pre-and post-tests; and interviews with students and teachers. Most of the research questions were investigated based on one major data source, and two or three supporting data sources. Multiple data sources were used to better understand the phenomenon under investigation, and support triangulation of the data for the purpose of increasing the validity of findings when the same themes emerge in different sources (Patton, 2002). Details of these data sources are illustrated below.
Online entries. Most of the participants’ interaction took place in the Knowledge Forum online environment, and all the written texts were saved in the Knowledge Forum database. This data was directly retrieved through the Knowledge Forum interface. The technology supported assessment tool, Idea Thread Mapper, also saved the students entries, including the idea threads, idea thread maps, and the “journey of thinking” posts for each thread. In this study, students’ discussion and reflection notes on Knowledge Forum, as well as the artifacts created by students on ITM (threads, maps and journey of thinking posts), was the major data source for the research question about how the assessment was conducted.

Social network data of online entries. Students’ log file information was retrieved directly from the Knowledge Forum database. Based on this log file information, the total number of notes created by each participant was computed. To understand the change of network pattern and the positions of individual members on the online discourse, the data about "who build on whose notes" was retrieved from KF. The build-on links were represented as valued case-by-case (member-by-member) matrix which indicated the frequencies of build-on links between each pair of participants in an Excel file. Each community members were shown as nodes, and each build-on links between two members was represented as “1” in the Matrix, and no build-on links between two members was noted as “0”. Then this data was analyzed through the embedded SNA tool on KF and NetMiner 4.0.

Class videos. All the ITM session classes were video-taped to record the details of the assessment activities as well as the interactions between the students,
teachers, and technology tools. Twelve class videos are all transcribed and analyzed,
including Class A’ four classes of collaborative assessment in Phase 1, four classes for
Class A in Phase 2, and four classes for Class B in Phase 2.

**Class observations.** The researcher observed all the ITM sessions and wrote
field notes, focusing on capturing the main activities of the teachers and students; and
recording how they sustain their idea development with the support of the assessment
result. In order to understand the inquiry process, the teachers and students’ knowledge
building discussions in their science and ICT classrooms were observed at least one or
two times a week. Altogether twenty class observations were generated. An observation
protocol was used to guide the class observation, focusing on understanding how the
tools and activities were used and what roles the teachers played (See Appendix K).

**Students’ performance in pre- and post-tests.** Students in Class A and Class B
both took pre- and post-tests in Phase 1 and Phase 2. The related part of the national standard
for science education for Chinese elementary schools can be found Appendix C. The test
papers for Phase 1 and Phase 2 can be found in Appendix D and E. The primary focus of
these tests was students’ deep understanding of the science content and inquiry skills.

After the tests were developed by the teachers and the researcher, the science
content was sent to a science education researcher of the Wuhou District, Mr. Tang, who is in
charge of science test development. He checked the content validity, and then determined that
the test items appropriately represented the science content of interest. A test of specification
(a form about how each test item represents certain knowledge and skills that are required by
the standard, see Appendix D and E) was created by both the test developers (the researcher and two teachers) and the expert separately. Then the results were compared. For the seven test items in Phase 1, there was disagreement about the knowledge and skills tested in item 6. For the nine test items in Phase 2, there was disagreement about the appropriateness of item 1. The discrepancies were discussed and the test items that did not represent the desired knowledge or skills were revised.

The test-retest method was used to provide evidence reliability. Ten students from other classes at the same grade level in the same school took the test twice within one week. A Pearson correlation was conducted to compare the scores (the value ranges from -1 to 1, and desired value is 1). The result showed that there was a strong, positive correlation between two test results: for Energy Unit, \( r = .99, n = 15, p < .0005 \); for Biodiversity unit, \( r = .98, n = 15, p < .0005 \).

Cronbach’s alpha was used to examine internal consistency of the tests. For the pre- and post-tests for Phase 1 which has seven items, the Cronbach's alpha is 0.803. For the pre- and post-tests for Phase 2 which has nine items, the Cronbach's alpha is 0.814. Both tests had high level of internal consistency.

**Interviews with students and teachers.** Two in-depth interviews with the two teachers and ten students were conducted. The teachers recommended ten students from both classes who were willing to share their ideas with the researcher, and were capable of clearly expressing their ideas. In Phase 1, two teachers and ten Class A students were interviewed. In Phase 2, two teachers and same ten students from Class A were
interviewed with follow-up questions, and ten students from Class B were interviewed with the initial protocol. Based on the research questions, the interview questions were guided by the Seidman’s (2006) in-depth interviewing protocol. The interview protocol for students and teachers can be found in Appendix A and B.

The first interview was conducted after the first phase, and the second was after the second phase. Each interview lasted 20-30 minutes with each participant. They were held in rooms on campus where privacy was assured. The whole interview process was audio-taped, transcribed, and kept anonymous.

In each interview, the teachers and students were asked to identify the good and bad assessment activities, and provided suggestions for the improvement of future assessment design. This data was an important source for the refinement of the assessment design in the new phase. It was also the triangulation data source for constructing a story about how the assessment was implemented.

To ensure the validity of the interview, the researcher used member checks in the interview with the teachers (Lincoln, 2002). Prior to the second interviews, the teachers were asked to verify researcher’s initial understandings of the major points from the preceding interviews. They agreed with most of my interpretations, and commented on the points that did not match their intentions. They also clarified some points that they did not express well in the interview, and added some details and examples elaborating the ideas they stated. The second interview was dedicated to reflection and member check as well (Seidman, 1991). This process ensured that the participants’ voices, rather than researches’ ideas, were
represented in the findings.

All the qualitative data in this study, including students and teachers' online entries, class videos, class observations, and interview with students and teachers was coded by two different coders. One coder is the researcher, and another coder is Ms. Zhang, an assistant professor in Jiujiang University of China. Her major is instructional technology and she is familiar with knowledge building theories. Both coders went through the Collaborative Institutional Training Initiative (CITI)'s training course about human research subjects, and got the approval for data access from the IRB office State University of New York at Albany. Many methods were taken to ensure the inter-rater reliability, which refers to “the extent to which different coders, each coding the same content, come to the same coding decisions” (Rourke, Anderson, Garrison, & Archer, 2001, p. 8). For instance, to determine the inter-rater reliability of the coding to students’ online entries, sample notes from the Knowledge Forum were selected. After having sufficient discussions to understand the knowledge building coding scheme, the sample notes were coded by the two coders, and more discussions were conducted if the agreement level among the coders was low (the value of Kappa coefficient is less than .70). After all the data was coded, the two coders cross checked the codes and disagreements were resolved with further discussions.

Since the school setting is in China, all the data is in Chinese. Both the second coder and the researcher are native Chinese fluent in English. In this case, all the data was not translated into English in the coding process, though the coding scheme is in English. When reporting the analysis result, the related data (examples) were translated into English. To
reduce the impact of researchers’ subjectivity on the findings (Merriam, 1998), peer review was provided by Ms. Zhang, the second coder, since she is fluent in Chinese and English. This scholar reviewed the researcher’s translations of the students’ and teachers’ statements from Chinese into English to ensure that meanings were not distorted. On the basis of this peer review, the researcher revised the selected statements and their translations.

**Data Analysis**

**Research question 1: How do students and teachers conduct the assessment of and for knowledge building?** The major data sources for this question were class videos and interview with students and teachers. Supporting data sources were class observations and students’ online entries on KF and ITM.

Holistic case study method was utilized in order to investigate how the assessment was conducted in the knowledge building practices. According to Yin (2009), case study is appropriate to answer the “how and why questions” (p. 9). In this study, the research question is a “How” question about the implementation of the assessment design in specific contexts. This approach was also selected because the researcher had little control over the events, and the contextual conditions of the school settings were relevant to the phenomenon under study (Creswell, 1998). To see whether different designs of the assessment brought the same or different influences to the way teachers and students conduct assessment, each class’ inquiry in two phases was treated as an embedded unit of analysis (Yin, 2009).

Since the assessment is a complex process, to avoid unfocused, repetitious, and
voluminous data analysis, the data analysis for this research question focused on two aspects:

1. The activities and tool features that enabled the teacher and students to conduct the collaborative formative assessment for knowledge building;

2. The roles of the teachers on supporting students' engagement in the assessment process.

Data driven coding (develop codes through reading of the material) was used to identify categories of data and major patterns or themes. First, repetitive patterns or themes from different data resources in each analysis unit (each class in one phase) were identified. Then, bigger common categories into which some of the summaries fit were formulated. After each embedded unit was analyzed, cross-unit similarities and differences were identified to build a more complete pattern or theme for the results (Yin, 2009). The major themes about the activities and tools which enabled the assessment conduction can be found in Appendix H, and the main roles of the teachers in the assessment process can be found in Appendix I.

Thick descriptions in data collection and analysis procedures were used to minimize researcher or inquirer effect. Multiple data sources, including class video transcripts, interview transcripts, and online entries from KF and ITM were used in order to better understand the phenomenon under investigation. They were used to support triangulation of the data, a procedure that increases the validity of findings when the same themes emerge in different sources (Patton, 2002).
Research question 2: Is the assessment of and for knowledge building associated with the advancement of the community’s inquiry? If yes, in what ways? The data analysis to this research questions will be illustrated in two sub-questions.

Sub-question 2.1: Is the assessment of and for knowledge building associated with students’ collaborative deepening moves in their online discourse to advance their knowledge? If yes, in what ways? The major data sources for this question were students’ online entries on KF and social network data of students’ online entries. The supporting data sources were class videos and students’ “journey of thinking” posts on ITM.

The deepening moves in students’ online discourse were analyzed through two aspects: (1) the change of contribution types of their online postings; and (2) the change of community’s social dynamics.

The change of contribution types of their online postings. Almost all the students’ notes on KF can be seen as contributions to the community, but they are different in terms of their impact to the community’s collective knowledge advancement. For instance, Zhang (2009) argued that if a community asked more explanatory questions than factual questions, then this community was pursuing self-directed goal instead of superficial understanding of the phenomena under investigation. Hakkarainen (2003) also stated that successful knowledge building is characterized by the generation of explanatory questions. This indicated that the distribution of the contribution types of the notes reflect the level of knowledge building quality.
To gauge the quality change of the students’ knowledge building discourse before and after the assessment, Chuy, Zhang, Resendes, Scardamalia and Bereiter’s (2011) coding scheme about contribution types of the online discourse was adopted to categorize student’s notes into six types: questions (Q), theories and explanations (T), evidences (E), referencing sources (R), connecting and integrating (C), and designing and applying (D). The questions are divided into six sub-categories: factual questions (Q1f), explanatory questions (Q1e), design questions (Q1d), idea initiating & wonderment questions (Q1i), idea deepening questions (Q2d), and idea clarifying questions (Q1c). The theories and explanations are divided into five sub-categories: intuitive explanations (T1i), alternative explanations (T1a), refined explanations (T1r), clarifying explanations (T1c), and suggestions for explanations (T1s). Detailed coding scheme can be found in Appendix F.

Two coders independently coded all the notes of two classes in two units. Cohen’s κ showed that there was a high level agreement between two coders (κ = .85, p < .0005). The different coding results were resolved through discussions. Then the distribution of the notes in each contribution types of two classes in two phases was compared and analyzed.

The change of the community’s social dynamics. Along with the knowledge building process, the community members advanced their knowledge through asking new questions and making more build-on notes to deepen their understanding. To understand the change of network pattern and the positions of individual members on
the online discourse, students’ SNA data was analyzed through the embedded SNA tool on KF and NetMiner 4.0.

The analysis focused on two major indicators of community’s social dynamics: network density and centrality index. By calculating the ratio of actual connections and potential connections of the community, the value of network density demonstrated how active the students participated in the interactions as a community. While centrality calculated the amount of information flow on an individual participant (direct in and send out), centrality index measured the variability of individual centrality scores. The in-degree centrality index measured how the various the participants were receiving links, and out-degree centrality represented how differently they were sending out links. The value of centrality index ranges from 0 to 1. A value of 0 indicates all actors have identical centralities (the engagement is equally distributed among all the community members) while value of 1 indicates only one central actor (the interaction concentrates on one person). In other words, the centrality index demonstrated the distribution of how students engagement (Freeman, 1979).

The value change of these SNA indicators in the two classes in two different time periods (before assessment activities and the whole inquiry) were compared in each phase. The reason that the time periods were not set as “before assessment” and “after assessment” was due to the continuation of the idea development. After the assessment, the students kept building on to the ideas that they initiated before the assessments. These notes should be calculated as linked to other notes. However, if
these notes were separated directly from the notes posted before the assessments and calculated the SNA value of these notes as a new set, the system would consider these notes as initiating notes instead of build-on notes. To avoid the misleading “cutting off” of the note links between the two periods, the current study calculated the SNA value of two time periods: before the assessment and the entire inquiry time. The change of the SNA value between the two time periods is also calculated. Although Class B did not conduct the designed assessment in Phase 1, for the purpose of comparing two classes the time point defined “before and after assessment” in Class A (10/21/2013) was also applied in Class B.

**Sub-question 2.2: Is the assessment of and for knowledge building associated with students’ individual understanding growth? If yes, in what ways?** The major data sources for this research question are students' reflection notes written to summarize their personal knowledge gain after collaborative assessment, and students’ depth of understanding shown in pre-and post-tests. Students’ “Journey of thinking” posts on ITM were used as a supporting data source.

To investigate the quality of the students’ reflection on the community knowledge advancement, students’ personal reflection notes (students individually summarized their knowledge gain through interacting with community’s knowledge advance) was analyzed. Content analysis (Chi, 1997) was used to examine students’ reflection notes written to illustrate their personal knowledge gain after the collaborative assessment. The quality of the notes was examined from three aspects: knowledge diffusion, depth of understanding, and
connectedness of the ideas. Details are illustrated below.

Knowledge diffusion: the number of important themes in collective knowledge covered in the reflective text. As Zhang et al. (2009) indicated, one way to analyze the increase of an individual student’s knowledge gain about diverse inquiry themes is to find out how many themes are stated in students' reflection notes. Each student's portfolio notes were divided into the smallest unit of text that conveyed a distinct theme, and then the number of the themes that were reported in students’ portfolio was recorded.

To be more specific, to compare the knowledge diffusion in different students’ portfolio notes the raters first generated a list of the themes covered in students’ online discussions. The students’ idea thread topics on ITM were used as the guideline for this coding process, and it was open to the topics that were not listed in the threads. The list of the themes generated by the raters can be found in Appendix J. After that, two coders read the students’ portfolio notes and identified how many themes were reported in their reflective text (κ = .84 , p < .0005). A two way repeated ANOVA was conducted to compare the two community’s performance in two phases.

Depth of understanding: the sum of level of scientific sophistication and epistemic complexity. Zhang et al.(2009) suggested that the students' depth of understanding can be represented by two ratings of their portfolio notes: scientific sophistication, and the level of complexity. Scientific sophistication represents the success a student has achieved in processing an idea at a certain scientific sophistication level. Galili and Hazan (2000) adopted a four point scale coking scheme to analyze scientific sophistication: 1=pre-scientific,
2=hybrid, 3=basically scientific, and 4= scientific. Epistemic complexity represents the level of complexity at which a student chooses to approach an issue, and Hakkarainen’s (2003) four-point scale (1=unelaborated facts, 2=elaborated facts, 3=unelaborated explanations, and 4=elaborated explanations) was used. The higher the complexity, the larger the proportion of cognitive effort required. Detailed coding scheme can be found in the Appendix G. Based on these two coding schemes two raters independently coded all the portfolio notes, and the inter-rater reliability was at a good level (for scientificness, \( \kappa = .83 \), \( p < .0005 \); for complexity, \( \kappa = .82 \), \( p < .0005 \)). A two-way repeated ANOVA was then conducted to investigate whether the add-up of the scientificness and complexity of two classes were significantly different in two phases.

Connectedness of the ideas: whether the ideas were stated in an inter-connected way. 

When writing portfolio notes, some students listed the ideas in a separate, isolated way, while some students described their knowledge in a connected, interrelated way. This reflects the cohesion of students’ understanding of the knowledge. For instance, one student wrote “what I have learned” in his portfolio note as following:

The new knowledge I learned in this unit included the following:

(1) Food chain
(2) Eco-system
(3) The extinct of the species (Class B, 12/26/201)

In this reflection text all the three themes (food chain, eco-system, extinct of species) were stated as isolated concepts without any connections. This note got 0% percent of connectedness.

Another student wrote the following portfolio notes:
What I learned in this unit included the following:

(1) To protect the diversity of species is protecting the food chain.

(2) The number of the animals needs to be balanced. If there is too much lamb and too few wolves, the amount of grass will decrease rapidly, and the grassland may turn into desert. (Class B, 12/26/2013)

This student’s explanation involves four inquiry themes: biodiversity, food chain, the relationship among the creatures, and the relationship between the creatures and environments. These four themes were all described in a connected, interrelated way. The biodiversity is connected with food chain, and the relationship among the creatures is connected with creatures and environments. In this case this note was scored 100% in connectedness.

Based on this rationale, two coders first decided whether each theme in the reflective text was stated in a connected, coherent way (each theme was coded as either connectedly stated or not connectedly stated). Then the number of connectedly stated themes was counted, and the percentage of connectedly stated themes out of the total number of the themes stated was calculated (Cohen’s $\kappa = .89, p < .0005$). After the connectedness of each note was decided, a two way repeated ANOVA was conducted to test the difference among two community’s performance in two phases.

*Pre- and post-tests.* As stated before the pre- and post-tests were designed to elicit students’ understanding performance by through asking students to explain understandings, solve problems, build arguments or construct products. The coding schemes about the depth of understanding (the scientificness and complexity) were also used to investigate students’ understanding performance (Hakkarainen, 2003; Zhang et al., 2007). Two coders independently graded all the items ($\kappa = .79, p < .0005$), and the differences were resolved.
through discussions.

Some items were only scored on scientificness, since the answer did not require detailed explanation. Then the final score of each item is the sum of these two values. The score of the depth of understanding on each item was added to reflect one student’s overall depth of understanding toward a certain topic. The full score for the pre- and post-test in Phase 1 was 76 and in Phase 2 it was 72. Since the two classes might have different level of pre-knowledge about certain topic, ANCOVA was used to compare the two community’s performance in their post-tests. The students’ performance in the pre-test was used as the co-variance to control the effect of different pre-knowledge to the two communities.
Chapter 4: Findings

In this chapter, qualitative and quantitative results of the data analysis are presented based on the research questions. The findings to research Questions 1 illustrated how the assessment was implemented in the specific context, and the results of questions reveals how the assessment related to students’ after-assessment inquiry moves.

Research Question 1: How do Students and Teachers Conduct the Assessment of and for Knowledge Building?

With the support of the teachers the students assessed three major attributes of their previous knowledge building achievement: community knowledge advancement, social dynamics, and individual understanding development. As designed these attributes were examined through a series of assessment activities. Most of the assessment activities were similar in three case study analysis units (Class A in Phase 1, Class A in Phase 2, and Class B in Phase 2). Below are the common categories of three analysis units.

How do students and teachers conduct the formative assessment of and for community knowledge advancement? As designed the community went through four major assessment activities: focus setting, evidence eliciting, evidence interpreting, and plan making.

Focus setting: clarifying inquiry intentions and criteria for success. To understand the status of the collective knowledge, the community first defined what should be the focus of their assessment. Together they looked at their previous discussions and tried to recall what important themes they had worked on. However, these themes were not evident in their
KF discussions; they were spread around in the hundreds of the notes. To dig these themes out, the students individually looked at the KF view to identify the “big ideas.” These “big ideas” were defined as highly interested and productive discussion centers. On their notebooks they created a list of “big ideas.” In the class discussion session the teachers projected the KF view on the screen. With the view interface as the reference, individual students proposed their ideas to the community. These proposals were challenged, synthesized and refined by other community members (the teacher or other students) according to the ideas’ level of importance and accuracy of the scope. After the consensus was reached, the teachers wrote these agreed “big ideas” on the board. This “big idea list” was used as the frame and guidance for the students to collect evidence in the next step.

Below is an example of how a class reviewed the individual proposed ideas. One student’s broad idea was split into smaller ones to better describe the focus of their previous inquiry.

Teacher: Can somebody tells me what important themes we have been discussed?
WSK: Plants.
Teacher: OK, plants. That’s WSK’s idea. Do you agree with him?
Students: Agreed.
Students: No…
Teacher: Some says agree, some says not agree. Those who do not agree, please tell us your ideas and reasons. ZX?
ZX: I think “plants” is too broad. We can find some sub-categories of this them.
Teacher: OK, sub-categories. What sub-categories?
ZX: Some like…like the living environment of the plants, and the different colors of the plants.
Teacher: Do you mean the characteristics of the plants?
ZX: Yes.
Teacher: OK, we got two important themes. (Write “the living environments of the plants” and “the characteristics of plants” on the whiteboard). (Class Video for Class A, 12/09/2013)

The activities and tool features in this procedure focused on making the big ideas
evident to the community. Generating “individual idea-lists” was an activity that made the ideas visible to the individual students, and reaching consensus about “class idea-list” was an activity that made the ideas visible to the whole community. The class discussion for making an “big idea list” was a conceptual artifact creating process that invited the whole community’s input.

**Evidence eliciting: collecting detailed evidence for achievements.** After the focal themes were established, the community started to trace the detailed developing trajectory of each theme as evidence of the development of collective knowledge. This evidence collecting process included three steps: (1) constructing idea threads with the selected notes; (2) creating “journey of thinking” for each thread; and (3) conducting authentic tasks.

**Constructing idea threads with the selected notes.** To trace the idea development in each theme, the students formed groups based on their interest to the theme. Each group had five to six students and used ITM to identify important online discussion notes for each focal theme of inquiry as an idea thread. These threads were further edited (removing unrelated notes, adding notes that were not found by the search engine, and highlighting important notes) through group discussion.

Some ITM features specifically support this process. For instance, the “search notes” function helped the students quickly find the notes that belonged to a certain theme. In the search engine box, the students typed in the key words; and then the notes with these key words came out automatically (the users can define whether the key words should be in the note title or in the note body) (see Figure 4.1).
Figure 4.1. The search function of ITM. The user can define the conditions for searching and type in the keywords in the search box. The system will automatically display the notes that contain the key words.

After the search result came out on the screen, the students reviewed the notes and then selected appropriate ones to construct the thread. This “reviewing” process was considered an opportunity for the students to get more accurate understanding of the idea development as they got chances to read all the notes related to this theme. In the interview, the students highlighted this activity for helping them find some notes that they had not previously read.

Student ZBX: When we were collecting the notes for the theme, we found some notes that we never noticed. For some reason they were not noticed...When sorting out the notes we need to read every note, and we found some valuable notes, and we didn’t notice them previously (Interview with Class A, 11/18/2013).

The search function also helped the students find the related notes in a previous inquiry. For instance, in biodiversity unit one group of Class A found the note titled “the food chain on the grasslands” very informative for explaining the relationship of the predators and primary consumers. The note was created in 2012 during their previous inquiry. They decided to add it into their current thread about “food chain,” and this inspired the whole class to
connect their previous contributions to their current inquiry (See Figure 4.2).

![Figure 4.2](image)

*Figure 4.2.* The food chain thread that connects students’ work in 2012 and in 2013. On the left are the notes that were posted in 2012, and on the right are the notes students created in 2013.

After the reviewing process, the students constructed the idea threads by clicking on “contribute to the thread” icon on ITM, and all the selected notes formed as one idea thread. On the “idea thread page” ITM automatically displayed a graph of the notes under a timeline, and it became a visible representation of the trajectory of the idea development (See Figure 4.4). This graphical of the idea thread helped the students understand the notes within a specific temporal context.

Student HTT: I like this stripe...
Interviewer: Under the timeline?
Student HTT: Yes. This stripe help me see when the note is posted, and better
understand the progress. Sometimes when you read a note posted very early, you think it sounds naive, we already know this idea now. But when you look at the time it is posted, you then understand, at that time period, we didn't discuss much about this, and this idea sounds reasonable at that point (Interview with Class B, Biodiversity Unit, 01/06/2014).

The students further edited the thread by removing the notes that did not belong to this thread, adding notes that were supposed to be in this thread, or highlighting the notes that were considered valuable to this thread (See Figure 4.4). In the interview, students consider these functions as very supportive on collecting evidence.

Student LYX: I like the "highlighting notes" function. When we see the valuable or high quality notes, we can highlight them, and then everybody can notice this note easily (Interview to Class A, Energy Unit, 11/18/2013).

*Creating “journey of thinking” for each thread.* After the thread was constructed and refined, each group collectively created a “journey of thinking” synthesis on ITM as a reflective textual representation of the idea development in this theme. By clicking the “journey of thinking” icon on the idea thread page, the students got into the “journey of thinking” page, and they specified their reflections in three text boxes: “we want to understand”, “we now understand” and ‘we need to do more” (See Figure 4.3). The students clicked on the “scaffold icons” to get scaffolds in the text boxes to facilitate their writing, such as such as “The questions we want to explore”, “We used to think” “Now we understand”.

The “journey of thinking” interface also provided a “historical record” function to support students’ collaboration on the reflective text writing. Once a student completed her writing or editing with the “journey of thinking”, she could click on “save” button, and the texts would be saved as a historical record. The students could check all the historical records
by clicking on the “historical record” button and made new contribution on these records. In the interview the students highlighted this function for helping them put group members’ thoughts together and continually improve the text.

Student ZZX: I like this feature.
Interviewer: The historical record? Can you tell me your reasons?
Student ZZX: This historical record shows us different versions.
Interviewer: Did you read different versions?
Student ZZX: Yes. We need to know what changes had been made. So we can put our ideas together. (Interview to Class A, Energy Unit, 11/18/2013)

Figure 4.3. The scaffolds on the “journey of thinking” page in ITM. The students could click on the icons to add the scaffold questions in the text box. They could also click on the “historical record” button to see the different version of their writings.

Conducting authentic tasks. Besides knowing “what we have done” on KF, the teachers believed that the other way to collect the evidence of the current collective knowledge could be exploring “what we can do with it”. In the interview after Phase 1 the
science teacher suggested that an authentic inquiry task may provide another way to detect the level of students’ collective knowledge. This suggestion was accepted by the researcher.

In Phase 2 when students got some knowledge for bio-diversity, they were invited to conduct a challenging task: to design a Moon Base for human being. The focus of the design is building a balanced eco-system. With the support of resources on tablets (such a drawing tools, graphics library, search engine), the students worked in groups to design a brief blueprint of their Moon Bases on the tablets with their knowledge about bio-diversity, food chain and ecological balance. Then each group presented their Moon Base designs to the classmates and explained their ideas about balanced eco-system behind these designs. They introduced why certain animals and plants were needed, how to keep ecological balance, and what the relationships among human being and these creatures were. Other community members commented and challenged their ideas after each group’s presentation. After that all the community reflected on the gaps and challenges they met on this task (Class observation, 12/10/2013).

In the interview, many students defined this inquiry activity as very useful on motivating them to reflect on their current knowledge.

Student YKL: The design of the Moon Base helped my reflection. This activity helped me to think, from the whole picture, about what animals or plants are needed to keep the balance of the food chain. Then they can thrive in it, and the Moon Base becomes a sustained eco-system. When you present your design to the class, people asked many questions. These all helped me to understand more knowledge. (Interview to Class B, Biodiversity Unit, 01/06/2014)

In the evidence collecting procedure the community created graphical (idea threads) and textual representations (Journey of Thinking) for the idea development of each thread.
These were time-consuming, labor intensive and cognitive demanding assessment work; it required the community to effectively collaborate within and across groups. The activities and tool features focused on supporting the collaboration, and making the conceptual artifacts visible and accessible so that the community can continually work on them. Some tool features (such as searching functions, and automatically generating thread graph functions) were designed to make the idea-thread constructing process easier, thus time and effort could be saved.

This evidence collecting process helped the students to get deeper understanding of the existing contributions by putting them in the temporal contexts, highlighting the valuable notes, and building the connections between the notes. This evidence also built a detailed visible representation of the current achievement in each thread, and this was necessary basis for the community to infer their knowledge status in the next procedure.

**Evidence interpreting: inferring current inquiry status and identifying deeper goals.**

After all of the necessary evidence was collected, the community started to put evidence together to infer the current status of the collective knowledge. The evidence included the graphical, statistical and textual representations of the idea development they created with the support of ITM, and the experience about the strength and limits of their current knowledge on dealing with authentic problems.

**Interpreting the representations on idea thread map.** To generate the interpretation of the collective knowledge status, the students read the “journey of thinking” text of other groups to get an overview with the detailed knowledge achievement of each theme. After that,
the students clicked on the “show map” function, and the ITM automatically generated an “idea thread map,” which displayed the idea thread graphs and statistics under a time line.

Two analysis charts were also displayed on idea thread map: the fan chart mapped out the note distribution across the threads; and a cross thread connection chart showed how close the threads are connected (See related functions of ITM in Figure 4.4). With the map of idea threads projected on a screen, the community collaboratively interpreted the progress of collective knowledge advancement. By comparing the achieved collective knowledge with the focal goals, the students identified gaps and challenges that needed to be addressed to further their inquiry.

Figure 4.4. The thread map on ITM. The green boxes highlight the functions that were
considered helpful to the students.

For instance, in energy unit, by interpreting the idea thread map projected on the screen, some students in Class A students found out the idea threads named “the generation of energy” and “energy transformation” had small numbers of contributions. They believed that these topics needed more contribution. Some students found that the theme about “the electromagnet and battery” and the “experiments about electromagnet” had many contributions, but still needed further exploration on the theories. One student pointed out that most of the notes about experiments are just plans for experiments; no results were reported, and no reflections of the experiments were generated. The class agreed that they should report the results to the community after the experiment was conducted. Through cross checking the threads displayed on ITM with the contents on their textbooks, the students also found that some important topics from the textbooks were not discussed - such as the magnetic poles, the use of electric motor, and energy from the sun (Class observation, 10/22/2013).

In the interview, the students highlighted the function of different representations on ITM. They believed that these graphical, statistical and textual functions helped them to see the whole picture of their current achievement.

Student WY: (The idea thread map) listed the quantity of the notes in each theme. I also see the names of each theme on this map. I can tell what topics my classmates like to discuss, what topics they do not like (Interview to Class B, Biodiversity Unit, 01/06/2014).
Student YKL: I like the Fan Chart. It shows how notes distributed. Then we will be able to find out what theme is not deep enough, then we can keep working on it (Interview to Class B, Biodiversity Unit, 01/06/2014).
Student JCR: (Pointing at the Cross-thread Connection Chart) I like this chart. On this chart, I can see theme 6 and theme 1 share nine notes. And some themes, such as theme
3 about "how energy exists" and theme 8 about "the production of energy" share very few notes. This tells me that theme 6 and theme 1 has closer connection (Interview to Class A, Energy Unit, 11/18/2013).

*Interpreting the evidences from the authentic tasks.* In Phase 2 After employing their collective knowledge in the authentic tasks, the community reflected on what knowledge has been applied in this inquiry task and what challenges and difficulties they met in this process. Based on that, they further discussed what gaps still existed in their current collective knowledge, and what they should do to address these issues.

For instance, after the groups presented their designs of “Moon Base,” the students of Class A found that most of the groups mentioned the differences between the primary consumers (grass eating animals) and predators (meat eating animals). None stated the appropriate ratio for these animals. The students of Class B found that besides the ecological balance issues, the other life-supporting issues, such clear air and water, correct temperature, and free of deadly cosmic rays also needed be considered. They found they had very little knowledge about these issues and they should further explore these topics in the future (Class observation, 12/11/2013).

Interpretation generating was a metacognitive process which invited the students to compare their current knowledge status with their desired cognitive goal, and then identify the gaps between them. The activities and tool features are designed to make the evidence visible to the community so that the community can have a better understanding of their current knowledge status, and thus make better comparison. These activities and tool features also support the community sharing information among individual students, small groups, and the class in order to better synthesize their interpretations.
Feedback providing: Planning for the deeper goals. After the community generated interpretations of their knowledge building status, they were ready to make plans to inform their next step knowledge building practice. Based on the gaps and challenges, the community made two types of plans: in groups they made plans for certain threads, and in class they made plans for their whole inquiry.

Group plans for certain threads. On the “journey of thinking” page, there is a text box titled “we need to do more.” This was the space for the group to specify their suggestions for the community’s next step inquiry on advancing that specific idea thread. The group who created this thread collaboratively generated the plan based on their reflection on “we want to understand” and “we now understand.” For instance, in the thread about “the mechanism of the electromagnet,” one group wrote their “journey of thinking” text as the following:

<We want to understand>
We need to understand how an electromagnet works.

<We now understand>
An electromagnet is composed of an iron core, a wire, and a battery.
The coil becomes magnetic when the current is switched on.

<We need do more>
We need to understand: Why does an electromagnet has two poles?
We need to experiment: Does the winding direction of the wire on the coil influence the magnetic pole of the electromagnet? (Class A “journey of thinking” text for “the mechanism of the electromagnet” thread)

This plan informed the whole class of the focus for their next inquiry. The community adopted these suggestions in their later inquiry. In the following weeks some theories about this topic were posted on KF, and some students designed and conducted the experiments about the magnetic pole change of the electromagnet. They reported the results of their experiment in the final presentation and articulated how Ampère’s circuital law can be
employed to decide the magnetic pole.

*Class plan for the community’s future collective inquiry.* Based on their interpretation of the idea thread map and their experiences in the authentic inquiry tasks, the community made their plan for their future collective inquiry through class discussion. Some questions were used to guide their discussions, such as: What important themes were not discussed? What themes need more contribution? What themes need deeper investigation and alternate perspectives? How can we make the discussions more coherent? Individual students proposed their ideas to the community, and through commenting and challenging each other, the community reached consensus about the plan. The teachers recorded the consensus on the board or on KF as a guide to the students’ future inquiry.

Below is an example of a class plan for next step inquiry.

In general:
1. We need to do more experiments and post the results and reflections of the experiments on KF;
2. People tend to build on the easy questions. We should challenge ourselves with the hard but valuable ideas.

About specific themes:
1. The important themes we haven’t discussed yet: the mini motors.
2. The themes that are very valuable but just had few contributions: how to avoid short circuit in the experiment of electromagnet? How the energy transferred when a coke can is crushed underfoot? How is energy transformed? How the electricity is generated?
3. The themes that had many contributions but still needs deeper thoughts and different perspectives: how other energy forms transform into electricity, how electromagnets are used in real life (Class A’s plan for energy unit 10/24/2013).

In Phase 2, the students used the feedback they got from the authentic tasks as the additional resource to inform the collective inquiry plan. After the two classes designed the “Moon Base,” students refined their class plan based on the feedback they got from this task.

For instance, the students in Class A added “finding out the appropriate ratio among the
animals in the food chain” as the new theme in their plan, and Class B added “consider air, water, temperature, and other issues for a sustained eco-system.”

The plans for certain threads and for the whole inquiry process were used as the vehicle for which students could better control their collective cognition process. They helped the students understand how the gaps could be filled, and what contributions were mostly by the community. The activities and tool features in this step focused on supporting the students to collaboratively make a refined plan based on individual proposals, and they also made the plans evident and accessible to realize its functions to the community.

How do students and teachers conduct the assessment of and for social dynamics change? With the support of social network analysis tool embedded in KF, the community reflected on their social network dynamics through interpreting the social network graphs. The teachers first projected the SNA charts (the Circle and Spring charts) from two periods (the first week and the second week) on the screen, and then invited the students to compare social network status as represented in the charts. Through discussion, the students understood what a good social network pattern should look like (dense interaction and distributed engagement). Based on this knowledge the students started to interpret SNA charts of their current inquiry (the fourth week). The students discussed how active the whole community was in making contributions, and who the active contributors were. After that, they made plans to adjust their social behavior accordingly. In the interview some students admitted that interpreting these graphs helped them to compare their activeness with other classmates, thus reminding them to be more active in the later discussion.

Student WXY: This graph shows people, shows us how much someone interacts with
other classmates. It’s like, some students got many arrows pointing to their nodes, and some of them only got one or two arrows. Some even got no connections, looks very lonely. So the other day LYX says she got very few connection lines, and her node looks very small. So she says she needs to make more connections with others. I think I need to be more active as well. I want to make my node looks bigger (Interview to Class A, 01/05/2014).

However, when interviewed, the teachers said they did not consider interpreting SNA charts very helpful. The inactive students’ participation on online discussions did not significantly change. The teachers believed that the underlying reason could be the gap between knowing “I need to do more” to “how to do more.” To the inactive students, they needed more “down to the ground” guidance, such as what topic they could make contributions, and how to make their notes more valuable. The general comment of “inactiveness” may make them feel “loosing face” in public instead of encourage them to actively contribute (Interview with the teachers, 11/16/2014). In this case, in Phase 2 the teacher refined this method. Instead of asking students to interpret the social network charts together, the teacher suggested the students check their social network status by themselves.

To help the students see the whole picture of the social dynamic change, the teacher posted a report note onto KF every week. In this report note the teacher presented the social network graph to the class, wrote a general report of the social dynamics change in this week, and provided some suggestions for later discussions. Following is an example:

Hi guys, if you take a close look at the above two graphs, you will see that the left graph is the contribution graph of last week, and the right graph is for this week. This week we got 16 more notes and the total note number on this view reached 99. I found many students were participating into the discussions about “who came first, eggs or chickens?” This is a very interesting topic but you have gone so deep, as WQY stated in her note, it has already became “A philosophical question”, you’ve already make it a philosophical argument. I think it’s time for us to switch to other topics. We can leave this topic for a while and maybe we can come back to this topic later (Ms. Yong’s post in Class A's KF view, 12/10/2013).
The other source of the evidence of the community’s social dynamic change came from the idea thread map. The graphical and statistical representations showed how the community’s participating behaviors changed over a certain time period. For instance, when interpreting their idea thread map, some students in Class A found an imbalanced distribution of the notes along the time. They pointed out that many notes were posted in the first week, but in the following two weeks there were very few postings. Through discussions the class inferred that the reason could be that the community was very active on asking questions in the first week, and in the later discussion period many students were reading other students’ questions or seeking explanations through reading books or searching online. They did not post enough build-on posts to make these questions go deep. Many questions faded out because of the lack of build-on contributions. The community agreed that they should engage in more build-on posts and make the ideas go deeper. This plan helped the community to adjust their social behavior accordingly (Class observation, 10/22/2013).

The reflection on social dynamics helped the students see the quality and quantity of their interactions with the KF community, and understand how their individual social behavior could influence the community’s social dynamics. However, these understandings did not directly influence students’ social behaviors. The students needed more information to fill the gap between “I know I need to do more” and “I know how to do more.” The activities and tool features which connected social dynamics with concrete knowledge building phenomenon (such as the notes distributions) were considered more helpful to the community.
How do students and teachers conduct the assessment of and for individual cognition development? To help the students collect evidence for their individual cognition development, the teachers asked the students to keep “portfolio notes” on KF. In the assessment sessions the students wrote reflective texts in their portfolio notes based on their previous records. Informed by the reflection results they wrote personal plans to address how they could further develop their individual cognition and contribute to the collective knowledge. Some questions were provided as the scaffolds for the portfolio note writing, including: (1) What knowledge I have learned for this topic; (2) How my ideas are improved along with the process (use one example); (3) My “aha” moments or the notes that really inspired my thoughts; and (4) How I can contribute to improve the community’s future inquiry. Below is an example of a students’ reflection for biodiversity Unit:

<What knowledge I have learned :>
1. The diversity of the creatures are crucial for a balanced eco-system, the relationship among the creatures are very complex.
2. There are many food chains in every eco-system, and these food chains together build up a food web.

<How my ideas are improved :>
Initially I don’t know the differences among the pigs and boars, and LXA’s note clearly stated the differences among these two kinds of animals. HYQ’s questions about the reason of these differences brought up the discussion about the effect of evolution. This helped me to understand that same type of animal can became different species in different environment because of evolution.

<My “aha” moments or the notes that really inspired my thoughts>
1. HSC’s note about “why penguins are birds” inspired me. This note helped me to understand that besides penguins, any creatures with these key characteristics can all be categorized as “birds”. Creatures in one biological group can have different appearances, and that makes our planet prosperous.
2. ZBX’s note “Why the animals change themselves to adapt to the environment” helped me to understand that the animals can always find ways to survive. Every animal has their own survival skills.

<How I can contribute to improve the community’s future inquiry>
I would like to contribute more ideas about the evolution.
I want to explore more about the appropriate ratios among the creatures in one food chain, such as the ration between the wolves and sheep (JCR’s Portfolio note for Biodiversity Unit, Class A, 12/26/2013).

In the interview the students considered writing personal portfolio notes as a very helpful activity on recording, reorganizing and synthesizing their individual knowledge.

Student LYX: I think writing portfolio is helpful. It’s like making a pearl necklace. You connect the pearls together and make a beautiful necklace. Writing reflection is connecting my records and making it looks nice (Interview to Class A, Energy Unit, 11/18/2013).

Student JCR: It helped my knowledge to be organized. It organized the knowledge I learned in this whole unit. I can see what discussions I participated, and what part needs to be improved. So I can do better in the next step (Interview to Class A, Energy Unit, 11/18/2013).

The scaffolds supported the students to organize their thoughts on reflecting and planning their individual cognition development. Through specifying their possible contributions in the next step inquiry, such as what threads they would like to participate more, what new ideas they wanted to initiate, and what new resources they could bring, the students connected their individual’s cognitive interest with the need of the community’s inquiry.

To sum the data showed that in the current study, the implementation of the assessment went through four major procedures on assessing the collective knowledge: focus setting, evidence collecting, evidence interpreting, and feedback providing. Through these four procedures the community portrayed the trajectories of the idea development of their previous collective knowledge, identified the gaps between current knowledge status and ultimate inquiry goals, and then defined the directions and methods for filling up the gaps. The activities and tool features focused on enabling the students to create and develop a series of conceptual artifacts along the assessment process. Some of them were designed or
emergent to make the conceptual artifacts evident and visible, some of them facilitated the high-level collaboration among the students, and some of them were designed to make the sustained idea development easier. The assessment of and for community’s social dynamics did not set up focus before collecting evidences since the focuses were predetermined. When assessing social dynamics change, the activities focused on connecting individual social behavior and the community’s dynamics, as well as bridging the social dynamics change with concrete cognitive actions. The evidences of students’ cognition development was elicited through writing reflective texts and making plans in their individual portfolios. The scaffolds helped the students organize their thoughts and connect individual interest to the community’s next step inquiry needs.

What roles do the teachers play to support students' engagement in collaborative assessment activities? The core idea that connects all of the categories about teachers’ roles was supporting the students to become active, capable assessors of collective knowledge. The students should have the control of the goals, progress and outcome of the assessment, and they should take the collective responsibility to ensure the success of the assessment. The teachers were helping them to shoulder these responsibilities. The data shows that the teachers fulfill this role from five major aspects: (1) supporting students on adopting their roles as active assessors; (2) supporting students’ conceptual change about working on collective knowledge; (3) supporting students on building criteria for accurate evidence; (4) supporting the information flow and idea development in different social levels; and (5) supporting students on taking advantage of technological affordances. Details are
illustrated below.

**Supporting students on adopting their roles as active assessors.** In the current assessment the students were supposed to be active assessors for setting up focuses, collecting evidences, generating feedback, and making plans. However, the traditional Chinese classroom culture and students’ long-term experiences of being passive test-takers made some students tend to be passive in the assessment activities, and wait for the teachers to give them the assessment results or detailed instruction for every step. The competitive tradition also made the students tend to focus on their own work (their individual work or their group work) since they were always preparing for competing with someone or some groups. It was challenging for the students to understand that their work was not for the sake of competing, but for advancing the inquiry of the whole community. This led to the students’ inactive participation in the assessment activities, and misunderstanding the purpose of their activities. In the interview the teachers described their worries about these issues.

Ms. Yong: I think students’ participation is an issue. They were not active enough in the discussions, and the class discussion became the stage of some high-achievers. I think I need to do something to change this situation (Interview to the teacher, Energy Unit, 11/19/2013).

Ms. Lee: I found many students only look at their own threads. They thought that the idea thread they created represents their group’s contribution instead of the class contribution on a certain theme. They believed that writing “journey of thinking” is a conclusion of their group’s achievement on this thread instead of the whole class’ achievement. They thought the plans they made in the “journey of thinking” was to guide one group’s inquiry instead of the whole class’ next step inquiry.

Interviewer: Why has that happened?

Ms. Lee: They thought group work is for the sake of the group. They wanted to outperform other groups. They were not collaborating. They were competing. (Interview to the teacher, Energy Unit, 11/19/2013)

To change the competitive and conservative classroom culture into a collaborative
and active culture, the teachers tried to make students’ commenting and challenging each other an idea shaping process instead of “fault picking” process. For example, in the energy unit after one group did their presentation about one thread, some students raised negative comments. The teacher asked the students:

Those suggestions are very helpful for this group to refine their work, do you agree, Group Four? On the other hand, this group spent a lot of time and effort to create this thread for us. Did you get any valuable take-away from this group? I think they did some things really good, but nobody mentioned any of them yet.

One student said she found that this group made a very good plan on the next step learning, especially the experiment plan. The teacher then said,

I like WSY’s comments. She found something valuable from this group’s presentation. Appreciating other people’s contribution is critical thinking as well. I hope the rest of you can do that in your comments (Video script to Class A, 11/15/2013).

By saying these words the teacher tried to make the ones who presented their work not feel “losing face”. Instead, they were honored as the responsible and valuable contributors to the community.

Besides encouraging active participation, the teachers also encouraged students to take active control in the assessment process. In the students’ previous experience it was always the teachers who controlled the assessment process; they decided what content should be assessed, when to conduct the activity, and in what ways they should complete the tasks.

In the current study, the teachers tried to help the students make these decisions. For instance, the teacher invited the students to discuss the goal of the current assessment activity, and then compare it to the final goal of the assessment. By doing this the students realized that there were still gaps between current achievements and their ultimate goal. Through discussions the teacher made the next step assessment activity the students’ collective decision instead of the
teacher’s will. Students’ sense of being active assessors was strengthened by teachers empowering them to make the important decisions about the assessment process.

The teachers also helped the students go through the conceptual changing process. This included seeing their group assessment products (idea threads and “journey of thinking” texts) as their contributions to the whole community instead of work for their groups. They considered other groups as cooperative partners instead of competitors. To fulfill this role the teachers sometimes directly emphasized the correct ideas in certain contexts. Below is an example.

Ms. Lee: What I am trying to say is, after you create the idea threads and wrote journey of thinking, did you find out any problems with your previous discussions? OK, Group 7, could you tell us what problems you found in the threads? Remember, these are not your group’s problems. Your group worked for the whole class. Your group found out the problems for the whole class, so everybody in this class will know what needs to be done with this topic (Video script to Class B, 12/24/2013).

They also invited the students to clarify the purpose of the group work. Through discussions the teachers helped the students understand that they were working on the collective knowledge, and they were doing it for the whole community. Below is an example.

Ms. Lee: Please think about this question: each of your group created one thread for a theme. Did you do this for your group, or for the whole class?
Students: For the whole class.
Ms. Lee: OK. Every group is making a contribution to the whole class' learning. Then I have another question: after I created the threads with my group members, should I only look at the thread that created by my group? Why? LRZ, what's your opinion?
Student LRZ: We need read other group's threads to improve our own thread.
Ms. Lee: For improve the thread you created? Student HJJ, do you have a different idea?
Student HJJ: I think we should read other groups’ threads, because we created the idea threads to help the whole class understand the current problems.
Ms. Lee: I think HJJ gave us a good reason for read other group’s threads. Yes, every group is creating the thread for the whole class. We should make best use of other group’s effort, shouldn’t we (Video transcript to Class B, 12/09/2013)?
The collaborative nature of the assessment demanded students’ conceptual change from working for an individual or small group’s benefit to working for the interest of the whole community. They also needed to change their motivation from competition to contribution. The teachers’ role is to make these changes happen and provide the necessary scaffolds.

*Supporting students on building criteria for quality assessment work.* In the current study most of the conceptual artifacts the community created in the assessment (including the focuses, evidences, representations, feedback and plans) were collaboratively generated by the community with the support of technical tools. The quality of these assessment products directly determined the success of the assessment. Only if these conceptual artifacts accurately represented the status of the current collective knowledge, the community would be able to find out the actual achievements and challenges, and then make an appropriate plan for upcoming inquiry. However, at the beginning of the assessment practice the teachers found that the quality of their assessment work tended to be low. For instance, in constructing idea threads many relevant notes were not selected, and some threads contained many irrelevant notes due to the lack of screening. Some “journey of thinking” text did not accurately describe the progress and problems of the thread development. They were either too simple to represent the real idea development progress, or stated unimportant progress instead of critical issues (Class observation, 10/20/2015). The students needed to understand the criteria for quality product to use these criteria to improve the quality of their assessment work. The teachers’ role was supporting the students to build their criteria instead of
imposing the criteria to the students.

The teachers used some measures to fulfill this role. They sometimes directly pointed out the problems in students’ work, then invited the students to discuss how the problems should be solved, and identify which characteristics defined accurate evidence. After that the students were asked to refine their assessment products based on these criteria. Below is an example.

Ms. Lee: I have been reading your journey of thinking yesterday. I found some groups are doing very good job on reflecting the progress of threads. However, some groups did not record the real progress in their work. Let’s take a look at some examples. Check out this "journey of thinking". What parts of this writing are well written, and what parts have problems?
Student ZX: I think they did a good job on writing "our progress". But they wrote very little about "we need to do more".
Student LJN: Yes, we do have some things not written.
Ms. Lee: You mean you did not write detailed suggestions for the development of this thread?
Student LJN: No, we did not write much. We planned to write more, but we did not have enough time on ICT class.
Ms. Lee: A good “journey of thinking” should not only make good reflection on the progress, but also a good plan to help us to see what should be done next. Could your group refine your “journey of thinking” in the next ICT class?
Student LJN: Sure (Video transcript to Class A, 10/21/2013).

The teachers also invited the students to reflect on the problems by themselves, and based on these problems the community tried to find out what made good assessment work.

Ms. Lee: Based on the fan chart, what topics are most popular?
Student WSK: “How to make an electromagnet” and “other issues”.
Ms. Lee: Someone says the “other issues” looks too big. Do you know the reasons?
Student WQY: This thread is not carefully screened.
Ms. Lee: How do you know that?
Student WQY: It got many notes that belong to other threads. This thread is supposed to include the notes that do not belong to any specific topics.
Ms. Lee: So this map is not accurate?
Students: No.
Ms. Lee: What makes an accurate map then?
Student HYQ: The threads are screened.
Ms. Lee: Yes, big threads need careful screening. We also have some small threads. I found they did not include all the notes that actually belong to them.

Student HYQ: Some notes are left out.

Ms. Lee: Right. An accurate map is made by accurate threads. We had some threads that have irrelevant notes, we also have some threads that left out the right ones. What can we do with it?

Student GYJ: We can refine the threads.

Ms. Lee: That’s good suggestions. Let’s do that in your next ICT class. Make sure your thread include all the notes that belong to this topic. No irrelevant ones. No left out ones (Video script to Class A, 10/22/2013).

The other measure that the teachers took was asking them to rate other students work. When some students completed their “journey of thinking,” the teacher invited them to read other groups’ work and give them scores (the score ranked from 1-5). The scores are used as the tools to encourage students generate their own criteria. No rubrics were provided, but the students were required to write down at least one reason for their scoring. In the next class the teacher invited some students to share their scoring reasons, and then invited the students to discuss whether these reasons were reasonable. Based on this discussion the whole class generated a list that described characteristics of the quality “journey of thinking:”

- Clear statement of the questions (no important topics missed);
- An accurate conclusion to the idea development progress (no important events missed, big achievements highlighted);
- Reasonable suggestions for the future idea development (clear, feasible, and really address the problems) (Class observation, 12/24/2013).

When students were writing their individual portfolios, the teachers used the same technique. They asked the students to rate other students’ portfolios (each student was required to rate at least two other students’ work) and write their reasons. Then the whole class discussed what made a good portfolio note based on their experiences. They then built synthesized criteria for the whole community.

In the interview Ms. Lee stated that helping students build the criteria for these
assessment artifacts was a critical role of the teacher, especially at the beginning of the assessment process. She spent a lot of time on these discussions with the students, and she believed it was worthwhile since it could ensure the success of the current assessment as well as the assessment in next phase. In Phase 2 she spent much less time on discussing the criterions with the students since they’ve already understood the major characteristics of quality work (Interview to the teacher, Biodiversity Unit, 01/05/2014).

**Supporting the information flow and idea development in different social levels.**

The current assessment was a collaborative effort of individual students, small groups, and the whole class. Complex information flow was produced among these social levels. For instance, the individual student’s ideas needed to be shared with the group members and the classmates, the information of the idea threads needed to be shared to other groups, and the class consensus needed to inform all the individual student’s actions and plans. The assessment was also a sustained idea development process. The ideas about the evidences or the feedback usually emerged from individual students, then they are enriched, shaped and deepened through discussions, and finally became the consensus of the group or the class. The group consensus also needed to be refined and synthesized to become class consensus. The complex information flow and idea development processes needed the teacher’s coordination and support.

**Facilitating idea generating and sharing.** Most of the conceptual artifacts started from individual student’s ideas. These ideas were generated by individual students, and then reviewed and synthesized in groups or in a class. To help students generate ideas the teachers
usually asked probing or open-ended questions. For instance, Ms. Yong invited the students
to reflect on their inquiry progress by saying:

Ms. Yong: Now we are reaching the end of this unit. Let’s recall our progress together. From the very beginning to present, what big steps did we go through? Who wants to tell us? OK, WQY (Video script to Class A, 11/15/2013).

To exhaust all the possible ideas from the community, or exhaust all the possible
perspectives for one idea, the teachers usually invited individuals to contribute their ideas
through calling out the students’ name (from the ones who raised their hands). They used
questions like “XX, What is your opinion?” “Could you tell us your idea, XX?” “I think XX
has something to share. Would you like to say it now?” They also use eliciting sentences like
“Any other ideas?” “Do you all agree with this list?” “I’m expecting more perspectives about
this issue…” These questions urged the students to contribute as much as possible in the
discussions, and provided opportunities for more students to participate.

There were occasions when the topics were too challenging for the students to
generate their own ideas or opinions. Under these circumstances the teachers usually
provided some scaffolds to help the students. For instance, in the Energy Unit Ms. Lee found
that the students had difficulties finding the connections among the idea threads. She then
projected a diagram created by a group of Canadian elementary school students on the screen.
On this diagram the Canadian students described the connections of eight topics they
discussed about “energy.” The teacher first invited the students to guess the meaning of the
words and the lines on this diagram, and then asked whether they could do a similar thing
with their own inquiry. This scaffold helped the students overcome the cognition barrier and
make connections among their threads by themselves (Video script to Class A, 11/15/2013)
(See Figure 4.5).

Figure 4.5. Students are making connections between the ideas. The left photo is the diagram created by the Canadian elementary students. This photo was provided as example to the Chinese elementary students illustrating how to make the connections among the themes. The right photo is the students of Class A talking about the connections among the themes in their inquiry.

To facilitating the group proposing and sharing, the teachers worked as the organizer and coordinator in the group presentation to ensure the groups share their ideas to the community in an efficient and orderly manner. Below is one example.

Ms. Lee: Now I want to invite your groups to come to the front to share the information of the threads. Before that, I want to remind you the rules of group presentation: First of all, time limit. Each group has three minutes to present your ideas. Second, the ones who sit down there please listen carefully when they present. If you have any questions and comments, please raise your hand when they finish their presentation (The teacher set up rules for group presentation) (Video script to Class A, 11/13/2013).

Facilitating idea shaping and synthesizing. The ideas proposed by individual or groups are “raw materials” of their consensus to the community. All of the information was
brought to public scrutiny, and it needed to go through a process of refining, synthesizing and developing before being accepted by the whole community. To facilitate and coordinate the idea shaping process among the community members, the teachers usually used questions that exhausted all of the comments and challenges from the students, or provide teachers’ questions and challenges. In the interview the Ms. Yong stated that one of her important roles in the assessment was to help the community make unclear ideas clarified, ill-defined ideas redefined, ill-expressed ideas rephrased, too-broad ideas be split into smaller ones, and too-detailed ideas integrated into bigger ones. Following is an example.

Student QSY: One example is when boil the water, there is energy transformation.
Ms. Lee: Could you specify how the energy is transformed?
Student WSK: When boiling the water, the heat transferred to the pot, and then the pot transfer the heat to the water.
Student LYD: The heat does not transform into any other energy.
Ms. Lee: Should we say energy transferring or energy transformation then?
Students QSY: Energy transferring (Video script to Class A, 11/15/2013).

Facilitating consensus reach. After the idea proposing and idea shaping, the community needed to synthesize the ideas and reach a rise-up consensus. As Ms. Lee stated in the interview, the final consensus did not need to be perfect, but she hoped she can help the community to go through a challenging process to improve their initial ideas (Interview to the teachers, 01/07/2014). Ideally the community should exhaust all the different opinions, resolve all the disagreements and conflicts, and then reach consensus naturally. However, without teachers’ support the consensus might never be reached. The students could keep fighting for their own ideas and never agree with each other. The teacher played the role of an authority figure to finalize the consensus, including accepting the appropriate proposals, rejecting the inappropriate proposals, and highlighting the valuable ideas. Below are some
examples.

(Students were proposing big ideas in their discussion in energy unit)
Student F: Energy transferring should be a big idea in our discussion.
Ms. Lee: Energy transferring? That’s a really good one. Let me write it down
(Accepting appropriate proposals) (Video script to Class A, 10/22/2013)
(Students were making inquiry plans)
Student Z: We didn’t discuss “the magical electric motor” on page 58.
Ms. Yong: Somebody already mentioned it. It’s already in our list. This belongs to the section about “the topics we haven’t discussed”. Now we are talking about the topic we have discussed, but not deep enough. Do you have any ideas with this one (Rejecting students’ inappropriate proposals) (Video script to Class A, 10/23/2013)?
(In the “commenting time” after one group’s presentation)
Student WJX: The multimedia is an example of energy transformation. It transforms the electricity into light, sound, and heat.
Ms. Lee: Did you hear what student WJX just said? He says the multimedia I am using now, is transforming electricity into light, sound, and heat. Isn’t it a wonderful example of energy transforming (Highlighting the valuable ideas) (Video script to Class A, 11/15/2013)?

In an attempt to ensure that consensus had been reached, the teachers always sought the community’s confirmation by asking: Do you all agree with this idea? Anyone got different ideas? Those who object with this idea, please state your reasons.

After the consensus was reached, to make the consensus evident the teachers also invited the students to make conclusions about their agreed ideas.

Ms. Yong: OK, today we had many discussions about the idea thread map. Who can stand up and make a conclusion about our discussion results? (Invite the students to make the conclusion about the consensus) (Video script to Class B, 12/12/2013).

Sometimes the teachers made the conclusions for the community.

Ms. Yong: OK, we just reviewed the big steps of our inquiry. We went through all this process. We also understand that the quality of our learning not only depend on the quantity of the notes, but also the quality of these notes. We also found out how to highlight the valuable notes in the threads. Now let’s get to the details of our achievements (Teachers making conclusions about the consensus directly) (Video script to Class B, 12/24/2013).

Facilitating students’ connecting consensus to their individual cognition. The consensus
needed to go back to individual students’ minds to fulfill its meaning. To support students on building the connections between the community consensus and their individual minds, the teacher tried to make the consensus evident and accessible to the students. They recorded the consensus in the public place (such as white board in the classroom) so that every community members could see it. To help individual students have long-term access to their consensus, the teachers also posted these consensus notes on the online discussion interface. When the students worked on their individual work (such as writing an individual plan), they could always check the class plan and make connections to it.

The other measure that teachers took was providing scaffolds for students’ reflection text. The scaffolds like “How I can contribute to improve the community’s future inquiry” guided the students to think about how their individual cognitive actions can connect to the community’s needs, so they can make better contributions to the community’s future inquiry.

The teachers also invited the students to discuss how their individual work connected to the community’s consensus. For instance, when the students were writing their individual plans, the teacher found that many students composed their plan based on their personal interest. Very few individual plans addressed the needs of the community. The teachers then invited some students to share their experiences on making individual plan based on the directions stated in the class plan.

To help the students work as an effective and productive community on assessment, the teachers needed to coordinate and guide complex information flow among different social levels. They also needed to bring the whole community’s cognition to a higher level through
Supporting students to take advantage of technological affordances. To the students the ITM was a brand new tool, and they need the teachers’ guidance and support to understand when, how, and why to use the ITM functions in the assessment activities. To fulfill this specific role the teachers first stimulated students’ epistemic need of using the technical tools. Instead of imposing the tools on the students; they tried to motivate the students to adopt the tools based on their own epistemic needs. Before the students used ITM to sort the notes, the teacher asked the students to write down the big ideas to classify the notes in their notebooks. Then she invited the students to speak about the problems they met when classifying the notes. Many students mentioned that they were overwhelmed by the big number of the notes and they felt this work was very time consuming. The teacher introduced ITM a new tool that could help with this issue. This stimulated the students’ epistemic needs on using the new tools and they were eager to learn how to employ the function to increase the efficiency of their work (Class observation, 11/20/2013).

To help the students get familiar with the basic function of the technical tools, the teachers usually demonstrated the basic tool functions with an example. When creating threads, Ms. Yong used one theme as an example to illustrate how a thread can be created on ITM. She created the thread on her desktop and broadcasted her screen to the students so that every student can see the steps on their own desktops (Class observation, 10/21/2013).

The detailed functions of the tools were not introduced. Instead the teachers encouraged the students to explore the detailed functions through trying and guessing. Below
is an example.

(Ms. Lee was projecting the idea thread map on the screen)
Ms. Lee: Have you tried these icons on the timeline? Who would like to share your experience?
LYX: Just now I clicked on "show build on links", and these lines show up on the map.
Ms. Lee: What do these lines mean?
Student LYX: I guess the lines show the build on lines of the notes. One note builds on another on KF.
Ms. Lee: Do you agree with her? The ones who agree with her please raise your hands. Yes, LYX is right. It shows the build on connections of the notes. It’s same with KF.
Anyone tried other icons (Video script to Class B, 12/09/2013)?

When the students working on their assessment products individually or in groups
with the support of technical tools, the teachers usually walked around in the classroom and
provided technical assistance when it is needed. They also encouraged students to describe
their technical problems in the class discussion, and then asked the know-how students to
share their tips.

(After the students tried creating their threads)
Ms. Yong: Have anyone experienced any technical problems?
WSK: My problem is some notes from KF cannot be found in the search engine in ITM.
Ms. Yong: You mean you cannot find certain notes through typing key words? Who can help her on this issue? ZHZ?
Student ZHZ: You can type in the whole title into the box, and then search it. You can also copy the title and then paste it in the search box.
Ms. Yong: Has someone tried this method? Does it work? OK, Group 7 and Group 8 said it works. Thank you, ZHZ. That's a very useful tip (Video script to Class A, 10/22/2013).

Overall the teachers played a very critical role in the current assessment activities. They
helped the students overcome cultural and cognitive barriers to work as active assessors, and
supported them to complete the conceptual change from working for their own interest to the
community’s need. They also facilitated the students building the criteria for the assessment
work so that the quality of the assessment could be ensured. They provided guidance and
support for the students on idea sharing, idea shaping, and consensus reaching. They also stimulated student’s epistemic needs on using technical tools to support their assessment process, and helped the community find out when and how the tools should be used. Many measures were taken by the teachers to serve these needs, and these measures are all emerged from the assessment process.

**Research Question #2: Is the Assessment of and for Knowledge Building Associated with the Advancement of the Community's Inquiry? If yes, in What Ways?**

2.1. *Is the assessment of and for knowledge building associated with students’ collaborative deepening moves in their online discourse to advance their knowledge? If yes, in what ways?* To find out what role the collaborative assessment played on deepening students’ online discourse, content analysis was conducted to compare the quality of the idea improvement moves (contribution types) before and after the collaborative assessment. The role of the collaborative assessment in the community’s social network change was investigated through social network analysis to students’ online discourse. Details of the analysis are illustrated below.

*Content analysis: Is the formative assessment associated with the deepening moves in students’ online discourse?* The results of the contribution types for the questions can be found in Table 4.1, and the details of for the distribution of the contribution types in the build-on notes can be found in Table 4.2.

*The contribution types of questions.* As Indicated in Table 4.1, in Phase 1 when Class A conducted assessment and Class B did not, before assessment factual questions were the
dominant component of the questions in both classes (66.67% for Class A and 52.46% for Class B). Very few questions were higher level initiatives such as explanatory questions, idea initiating wonderment, or design questions. Pearson’s Chi-Square test also showed that the difference among the two classes were not significant ($\chi^2(5) = 10.66, p > .05$).

After the assessment, the major division of the questions in Class A became idea-deepening questions and elaborating questions (40%), and the second biggest chunk is the explanatory questions (20%). Only 8% of the questions are factual questions. In the same period the major parts of Class B students’ questions were clarifying questions (36.84%) and factual questions (26.32%). The idea deepening/elaborating questions remains as minority (11.53% before and 10.48% after). Pearson’s Chi-Square test showed significant difference among the two classes ($\chi^2(12) = 132.76, p < .05$). This indicated that before the assessment the two classes had a very similar distribution of the contribution types for their questions, but after the assessment the students in Class A started to seek more high level initiatives to deep their thoughts, while Class B were still focusing on relatively lower-level questions (See Figure 4.6).

In the Biodiversity Unit, both classes conducted a refined assessment. Before the assessment the factual questions were still the primary part of the questions in both classes (45.45% for class A and 58.33% for class B). After the assessment, although the details of the question distribution varied between the two classes, the trend of the distribution change looks similar. The idea deepening/elaborating questions became the major question type in both two classes (31.03% for Class A and 25% for Class B). The percent of factual questions
decreased in both classes (Class A became 10.34% while Class B became 15.63%). This indicated that with refined assessment both classes shifted from superficial questions to high level idea deepening questions, which is very similar with Class A’s trend in Phase 1 (See Figure 4.7).

Table 4.1

*The Contribution Types of the Questions before and after Assessment in Two Classes’ Discussions in Two Phases*

<table>
<thead>
<tr>
<th>Contribution Type</th>
<th>Q1f</th>
<th>Q1e</th>
<th>Q1d</th>
<th>Q1i</th>
<th>Q2d</th>
<th>Q1c</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class A Energy</strong> Before</td>
<td>Note count</td>
<td>30</td>
<td>4</td>
<td>0</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Percent</td>
<td>66.67%</td>
<td>8.89%</td>
<td>0%</td>
<td>11.11%</td>
<td>6.67%</td>
</tr>
<tr>
<td>After</td>
<td>Note count</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Percent</td>
<td>8%</td>
<td>20%</td>
<td>8%</td>
<td>12%</td>
<td>40%</td>
</tr>
<tr>
<td><strong>Class B Energy</strong> Before</td>
<td>Note count</td>
<td>32</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Percent</td>
<td>52.46%</td>
<td>3.28%</td>
<td>3.28%</td>
<td>4.92%</td>
<td>11.48%</td>
</tr>
<tr>
<td>After</td>
<td>Note count</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Percent</td>
<td>26.32%</td>
<td>15.79%</td>
<td>10.53%</td>
<td>0%</td>
<td>10.53%</td>
</tr>
<tr>
<td><strong>Class A Biodiversity</strong> Before</td>
<td>Note count</td>
<td>25</td>
<td>14</td>
<td>0</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Percent</td>
<td>45.45%</td>
<td>25.45%</td>
<td>0%</td>
<td>5.45%</td>
<td>12.73%</td>
</tr>
<tr>
<td>After</td>
<td>Note count</td>
<td>3</td>
<td>8</td>
<td>3</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Percent</td>
<td>10.34%</td>
<td>27.59%</td>
<td>10.34%</td>
<td>10.34%</td>
<td>31.03%</td>
</tr>
<tr>
<td><strong>Class B Biodiversity</strong> Before</td>
<td>Note count</td>
<td>28</td>
<td>6</td>
<td>0</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Percent</td>
<td>58.33%</td>
<td>12.5%</td>
<td>0%</td>
<td>18.75%</td>
<td>4.17%</td>
</tr>
<tr>
<td>After</td>
<td>Note count</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Percent</td>
<td>15.63%</td>
<td>18.73%</td>
<td>3.13%</td>
<td>15.63%</td>
<td>25%</td>
</tr>
</tbody>
</table>

*Note*. The sum of the percent of some contribution types are over 100% due to the double coding of certain notes. Q1f refers to factual questions; Q1e refers to explanatory questions; Q1d refers to design questions; Q1i refers to idea initiating & wonderment questions; Q2d refers to idea deepening questions; and Q1c refers to idea clarifying questions.
Figure 4.6. Comparison between Class A and Class B for the contribution type of the questions in Phase 1 (Energy Unit).

Figure 4.7. Comparison between Class A and Class B for the contribution type of the questions in Phase 2 (Biodiversity Unit).
The contribution types of build-on notes. As Table 4.2 and Figure 4.8 indicated, in Phase 1 before assessment the key component of students’ build-on notes in both classes were intuitive explanations (58.11% for Class A and 41.58% for Class B) and referencing sources (24.32% for Class A and 29.21% for Class B). Pearson’s Chi-Square test also showed that the difference among the two classes are not significant (χ(8) = 8.57, p > .05).

After the assessment the Class A students contributed less intuitive explanations (it decreased from 58.11% to 36%), but more refined/sophisticated explanations (it increased from 5.41% to 20%). In contrast, Class B students brought even more intuitive explanations in the same period (it increased to from 41.58% to 62%). The refined/sophisticated explanations decreased from 8.91% to 4.95% in Class B. This indicates that the two classes went to divergent directions. The students in Class A were expanding and deepening their inquiry with more refined and sophisticated ideas, while students in Class B continued contributing relatively superficial thoughts to the community. Chi-Square test also showed that the difference among the two classes is significant (χ(18) = 343.6, p < .05).

In Phase 2, before the assessment intuitive explanation was still the major component in both classes (55.46% for Class A and 46% for Class B), referencing resources were the second biggest chunk of their build-on notes (26.05% for Class A and 34% for Class B). After the assessment the distribution changed in both classes. The students in both classes contributed less intuitive explanations (Class A decreased to 38.98% while Class B decreased to 35.71%). The proportion of referencing sources was also reduced (Class A went down to16.95% while class B dropped to 22.32%). The percent of refined/sophisticated
explanations increased in both classes (Class A increased from 8.4% to 12.71% while Class B increased from 2.67% to 16.07%) (See Figure 4.9). This trend is very similar with the trend of Class A in Phase 1.

Table 4.2

The Contribution Type of the Build-on Notes before and after Assessment in Two Classes’

Discussions in Two Phases

<table>
<thead>
<tr>
<th></th>
<th>Contribution Type</th>
<th>T1i*</th>
<th>T1a*</th>
<th>T1r*</th>
<th>T1c*</th>
<th>T1s*</th>
<th>E*</th>
<th>R*</th>
<th>C*</th>
<th>D*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A Energy</td>
<td>Before</td>
<td>Note count</td>
<td>43</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Percent (%)</td>
<td></td>
<td>58.11</td>
<td>0</td>
<td>5.41</td>
<td>5.41</td>
<td>4.05</td>
<td>0</td>
<td>24.32</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>Note count</td>
<td>45</td>
<td>12</td>
<td>25</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>25</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Percent (%)</td>
<td></td>
<td>36</td>
<td>9.6</td>
<td>20</td>
<td>7.2</td>
<td>0.8</td>
<td>0.8</td>
<td>20</td>
<td>5.6</td>
</tr>
<tr>
<td>Class B Energy</td>
<td>Before</td>
<td>Note count</td>
<td>84</td>
<td>2</td>
<td>18</td>
<td>14</td>
<td>16</td>
<td>1</td>
<td>59</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Percent (%)</td>
<td></td>
<td>41.58</td>
<td>0.99</td>
<td>8.91</td>
<td>6.93</td>
<td>7.92</td>
<td>0.50</td>
<td>29.21</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>Note count</td>
<td>62</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>7</td>
<td>0</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Percent (%)</td>
<td></td>
<td>61.39</td>
<td>3.96</td>
<td>4.95</td>
<td>3.96</td>
<td>6.93</td>
<td>0</td>
<td>4.95</td>
<td>0.99</td>
</tr>
<tr>
<td>Class A Biodivers</td>
<td>Before</td>
<td>Note count</td>
<td>66</td>
<td>4</td>
<td>10</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>31</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Percent (%)</td>
<td></td>
<td>55.46</td>
<td>3.36</td>
<td>8.40</td>
<td>3.36</td>
<td>0</td>
<td>0</td>
<td>26.05</td>
<td>4.20</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>Note count</td>
<td>46</td>
<td>10</td>
<td>15</td>
<td>12</td>
<td>5</td>
<td>0</td>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Percent (%)</td>
<td></td>
<td>38.98</td>
<td>8.47</td>
<td>12.71</td>
<td>10.17</td>
<td>4.24</td>
<td>0.00</td>
<td>16.95</td>
<td>6.78</td>
</tr>
<tr>
<td>Class B Biodivers</td>
<td>Before</td>
<td>Note count</td>
<td>69</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>10</td>
<td>0</td>
<td>51</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Percent (%)</td>
<td></td>
<td>46</td>
<td>2</td>
<td>2.67</td>
<td>3.33</td>
<td>6.67</td>
<td>0</td>
<td>34</td>
<td>5.33</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>Note count</td>
<td>40</td>
<td>3</td>
<td>18</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Percent (%)</td>
<td></td>
<td>35.71</td>
<td>2.68</td>
<td>16.07</td>
<td>2.68</td>
<td>5.35</td>
<td>0.89</td>
<td>22.32</td>
<td>8.93</td>
</tr>
</tbody>
</table>

Note. The sum of the percent of some contribution types are over 100% due to the double coding of certain notes. T1i represents intuitive explanations; T1a represents alternative explanations; T1r represents refined explanations; T1c represents clarifying explanations; T1s represents and suggestions for explanations; E represents evidences; R represents referencing sources; C represents connecting and integrating; and D represents designing and applying.
Figure 4.8. Contribution types of the build-on notes before and after assessment in two classes’ discussions in Phase 1 (Energy Unit).

Figure 4.9. Contribution types of the build-on notes before and after assessment in two classes’ discussions in Phase 2 (Biodiversity Unit).
As discussed in Chapter 3, the question types indicated what goals the community was pursuing on their cognition; factual questions direct to superficial understanding of the phenomena, while explanatory questions leads to self-directed inquiry (Hakkarainen, 2003; Zhang, 2009). Below are two examples:

**Factual question (Q1f)**: I need to understand: What is biodiversity?” (Class B, 11/13/2013)

**Idea deepening question (Q2d)**: If there are too many species in one system, will it be a lot of fighting among the species? Could that fighting leads to imbalanced eco-system as well? (Class B, 12/10/2013)

Although both questions are about a similar theme (the understanding to biodiversity), they led to different levels of cognition. The factual question led the understanding of factual information (the definition of biodiversity), while the idea deepening question usually seeks for higher-order idea development (including inferring, comparing, and explaining) based on the existing understanding about the biodiversity. The decrease of factual questions and the increase of the idea deepening questions could indicate that the community was changing their interest from understanding factual knowledge to seeking sustained deeper understanding, and their cognition interest was moving toward higher level.

When responding to other’s ideas, the type of the response reflected students’ cognition level as well. Two examples of the students discussion regarding “Who came first, chicken or eggs” is illustrated below:

**Intuitive explanation (T1i)**: I think egg comes out first. All the chickens came from the inside of the egg shells (Class A, 12/05/2013).

**Refined and sophisticated explanations (T1r)**: I believe that the eggs came out first. I saw a TV show explained this issue. When a new creature is born, it gets some genetic mutation. Every time the “ancestors” of the chickens reproduced, their gene changed a little. When an egg got the gene that was closest to the modern chicken, then the chicken came out as genetically modern chicken. This is why eggs came out first (Class A, 12/05/2013).
When posting intuitive explanations, the students were using their personal experiences and informal language to explain certain phenomena; when contributing refined and sophisticated explanations, they were using disciplinary concepts or terms which presented their theories and explanations. These usually involve justification, elaboration, describing specific processes or mechanisms. Obviously the refined/sophisticated explanations required higher level conceptualization and more cognition effort. Students changing their tendency from posting intuitive explanations to contributing refined/sophisticated explanations revealed that the students were deepening their ideas toward a higher-order cognition demanding direction.

Overall, the results indicated that the assessment in this study supported the quality improvement in students’ initiating questions as well as build-on contributions. With the collaborative assessment, the students asked less factual questions and more idea deepening questions; they also contributed more refined theories and sophisticated explanations instead of intuitive explanations and factual knowledge from other resources.

**Social network analysis: Is the formative assessment associated with the community’s social network change?** Social network analysis (SNA) was utilized to analyze two major indicators of community’s social dynamics: network density and centrality index. These SNA indicators were compared across two different time periods (before assessment activities and the whole inquiry). Detailed analysis results can be found in Table 4.3.
Table 4.3

**SNA Results of Two Classes in Two Units**

<table>
<thead>
<tr>
<th></th>
<th>Energy Unit</th>
<th>Biodiversity Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Class A</td>
<td>Class B</td>
</tr>
<tr>
<td>Members Count</td>
<td>39</td>
<td>39</td>
</tr>
<tr>
<td>Network Density</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Before*</td>
<td>5.26</td>
</tr>
<tr>
<td></td>
<td>Whole*</td>
<td>20.64</td>
</tr>
<tr>
<td></td>
<td>Change*</td>
<td>15.38</td>
</tr>
<tr>
<td>Centrality Index</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Before</td>
<td>.13</td>
</tr>
<tr>
<td></td>
<td>Whole</td>
<td>.52</td>
</tr>
<tr>
<td></td>
<td>Change</td>
<td>.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Before</td>
<td>.11</td>
</tr>
<tr>
<td></td>
<td>Whole</td>
<td>.26</td>
</tr>
<tr>
<td></td>
<td>Change</td>
<td>.15</td>
</tr>
</tbody>
</table>

*Note.* “Before” indicates the time period before the assessment, “whole” indicates the time period from the beginning to the end of the inquiry, and “change” indicates the difference of the value between these two periods.

The analysis of network density, as Figure 4.10 indicated, showed that in Phase 1 Class A had a bigger increase of its network density (15.38%) than Class B (10.19%) after collaborative assessment. When it came to Phase 2, the increase of the density became very similar (Class B, 18.54%; Class A, 17.29%).

The analysis of the centrality index showed that in Phase 1 Class A had bigger increase of in-degree centrality index (.39) than Class B (.23). Similar results were found on out-degree centrality index: Class A increased at .15 while Class B increased at .1. This indicated that along with the inquiry, both communities became more centralized in interaction instead of distributed engaged, and class A became even more centralized after the
assessment. In Phase 2 the result was mixed: Class A’s in-degree centrality index increase (.1) outperformed Class B (.03), and Class B’s out-degree centrality index increase (.13) exceeded Class A (.02). This indicated that in Phase 2 both two communities became more centralized along with the inquiry, but their engagement distribution did not have big difference.

![Figure 4.10](image-url) Network density change in two communities in two units. “Before” means the density before collaborative assessment, “whole” refers the density of the community in the study of whole unit.

The increase of students’ activeness could be related to the emphasizing of students’ active role in the assessment and students’ plans to improve their social dynamics. In the assessment activities, to make the metacognitive artifacts the product of community’s mental effort instead of a few high achievers’ ideas, the teachers tried many methods to encourage active participation. For instance, in one class discussion about how to improve the quality of the idea thread map, at the end of the discussion the teacher showed her appreciation for students’ active participation by saying:

I found today the whole class is carefully listening and actively participating into the
discussion. This is a big improvement. So many students are contributing to our assessment. You are really working as active assessors. I am so proud for you. I had wonderful experience today. Well done. Thank you (Video script to Class A, 10/22/2013).

Some positive change the community achieved in the assessment could be transferred into the latter inquiry. Moreover, the students’ interpretation of their social dynamics made them understand why the participation needed to be improved, and the community’s plans informed them how their social dynamics could be improved. These could all help the students to improve their activeness in participation.

Although overall students’ participation increased after assessment, the increase was not evenly distributed among the students. On the contrary, the differences among the students became even bigger after assessment. A close look at the online discussions showed that the communities started their inquiry with everybody posting their initial questions on KF. Then the community read these questions, and responded to the questions that were of interest. At this stage the differences among the students’ engagement were very small. After that community went through a natural idea evolving process in opportunistic collaboration environment. Along with the time some factual questions like “What is energy? ” (Class A, 09/13/2013), “What is energy transformation?” (Class A, 09/17/2013) got little build-on notes and gradually faded out. On the contrary some questions which initiated idea wonderment, such as “How do people get energy besides eating food?” (Class A, 09/17/2013), became the center of discussions. The students tended to spend more effort on centers of discussions, and these centers became bigger along with the time. This “positive feedback”
loop made the students who initiated these promising ideas got more chances to interact with other people.

Compared with the “natural idea selecting” process in the assessment, the inquiry with assessment added an intervention to students’ idea selecting. The assessment asked the students to identify the discussion centers of their collective knowledge, and through interpreting the evidences the students planned their future focuses. These plans could make the discussion become even more focused, since these plans encouraged the students to spend more effort and time on the common goals. The students who initiated these topics or the ones who have more interest and resources with these topics would had more interactions with other students, and this may cause the increase of the differences among the students’ engagements.

In conclusion, the results of SNA indicated that the community who conducted assessment had a bigger increase in its social network density. The results also showed the increase of the centrality index in all the communities (with or without assessment) along with the inquiry process, and the community who conducted assessment became even more centralized.

2.2: Is the collaborative assessment associated with students’ individual understanding growth? If yes, in what ways? The data set for this research question was the students’ portfolio notes and students’ pre- and post-tests. Content analysis was conducted to analyze these two data sets.
Is the formative assessment associated with the quality change in students’ portfolio notes? As discussed in Chapter 3 the quality of students’ portfolio notes were evaluated through three aspects: knowledge diffusion, depth of understanding, and idea connectedness. Detailed analysis results can be found in Table 4.4.

Knowledge diffusion. A two-way repeated measure of ANOVA was conducted to analyze the number of themes covered in students’ portfolio notes. The analysis result showed significant differences among the two phases $F(1, 34) = 7.3$, $p<.05$. No significant difference was found in the interaction of class and phase. The difference among the two classes was not significant either. This indicated that that in Phase 2 students of both classes covered more themes than they did in Phase 1.

Table 4.4

<table>
<thead>
<tr>
<th></th>
<th>Class A</th>
<th>Class B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Themes Covered</td>
<td>Scientificness+</td>
</tr>
<tr>
<td>Energy</td>
<td>M 4.83</td>
<td>5.4</td>
</tr>
<tr>
<td></td>
<td>SD 1.84</td>
<td>1.89</td>
</tr>
<tr>
<td>Bio-diversity</td>
<td>M 5.11</td>
<td>6.6</td>
</tr>
<tr>
<td></td>
<td>SD 1.57</td>
<td>1.44</td>
</tr>
</tbody>
</table>

As discussed in Chapter 2, between the individual understanding and the community’s collective knowledge there is a “macro-micro” connection line: individual cognition contributes to the community knowledge, and the community knowledge informs the students’ individual cognition. However, the community knowledge advancement does not equal individual advancement. Each individual student internalized some of the
community knowledge and made them their own understandings. For instance, in Phase 1 for Class A students, thirteen themes were discussed, eight of them were selected as idea threads, and the average theme number discussed in their portfolio notes was 4.83. In Phase 2 among 11 themes discussed, the students of Class A covered 5.11 themes on average. The students of Class B had a similar increase with their theme coverage. The increase of the theme coverage from Phase 1 to Phase 2 showed that the breadth of students’ personal understanding increased, and the connection between their personal understanding and the community knowledge also became stronger. This could be attributed to the refined assessment in Phase 2 as well.

*Depth of understandings.* The students’ depth of understanding of the portfolio notes were represented by adding up the level of scientific sophistication and the level of complexity of their reflective texts. The mean of multiplying scientificness and complexity of students’ portfolio can be found in Table 4.4. A two-way repeated measure of ANOVA was conducted to analyze the depth of understanding value of students’ portfolio notes (adding up of scientificness and complexity). The results indicated significant difference between two classes: \( F(1, 34) = 11.44, p < .05 \). The difference among the two phases was also significant: \( F(1, 34) = 23.49, p < .05 \). The interaction among the phase and class was not significant. This means that the depth of understanding showed in Class A students’ portfolio was significantly better than Class B in both Phase 1 and Phase 2, and both classes performed better in terms of depth of understanding in their portfolios in Phase 2.

As stated before when writing portfolio notes four scaffolding questions were
provided: (1) What knowledge I have learned for this topic; (2) How my ideas are improved along with the process (use one example); (3) My “aha” moments or the notes that really inspired my thoughts; and (4) How I can contribute to improve the community’s future inquiry. The differences of the depth of understanding were mainly determined by their answers to the first question. In the Energy Unit most of the students listed their understanding without elaboration or explanation, and there were also many imprecise scientific ideas. Below is an example:

What knowledge I have learned for this topic:
(1) Energy cannot be produced or eliminated. It can only be transformed from one object to another. Only the “big bang” can eliminate the energy (Elaborated facts; hybrid scientific ideas).
(2) The pros of recycling the used coke cans are: the materials are saved, and the energy is saved. The cons: When processing the used coke cans, some waste is produced and some harmful substance might get into the air and became new pollution to the earth (Unelaborated facts; basic scientific ideas).
(3) When you step on a coke can, your foot sends motion energy to the can, and this pressure makes the chemical energy come out from the coke can, and the coke can is then crushed (unelaborated explanations; pre scientific ideas).
(4) Energy saved in the objects when it is moving or not moving (unelaborated facts; pre-scientific ideas).
(5) The power of electromagnetic is related to the wire turns on the coil, the electric power, and the size of the iron core (unelaborated facts; scientific ideas) (QKX’s portfolio, Class B, 11/1/2013)

In the Biodiversity Unit, the students’ statement for question 1 tended to be more scientific and more elaborated. Below is the same student’s portfolio note for Biodiversity Unit:

What knowledge I have learned for biodiversity:
Every species is the important member of the eco-system. Through food chain, the species rely on each other and restrict each other. When there is a problem in the food chain, the balance of the whole eco-system could be impacted. For instance, when people overly hunt snakes, then the number of snakes could rapidly drop down, and then the rats could became a disaster. When people hunt down too many birds for pets,
then the worms, such as pine moths, locusts could eat up many trees or crops. This ecological imbalance could bring great loss to the forest and farmers (Elaborated explanations; scientific ideas) (QKX’s portfolio, Class B, 01/08/2014).

The differences of students’ performance in their reflective texts between the two phases might be attributed to the refined assessment in Phase 2. The assessment could help the students better understand the shared ideas through having students reviewing the notes in constructing the idea threads. Some in-precise ideas were corrected in the group or class discussions in the assessment activities. However, the result could not rule out the influence of the different content of two phases: the knowledge about biodiversity could be more easily elaborated compared with energy; and the ideas about biodiversity could be less challenging in terms of the scientificness compare with the ideas about energy to these grade six students.

The differences of the depth of understanding between the two classes could also relate to the initial differences on the two classes’ ways of inquiry. Some students in Class A tended to bring out deep questions which always move the inquiries to the next level, and the general depth of Class B students’ thoughts could not match Class A students’ ideas.

**Connectedness of the ideas.** The result of a two-way repeated measure of ANOVA analysis to the connectedness of students’ portfolio notes showed significant difference between the two phases, $F(1, 34)=18.67$, $p<.05$. No significant difference was found between the two classes. The interaction between Class and Unit was not significant either. This indicated that the students significantly improved their idea connectedness in their reflective text in Phase 2.
The connectedness of the ideas could relate to the assessment in Phase 1. At the end of the Phase 1 inquiry the community conducted a group presentation, and on that presentation the community discussed the connections among the ideas they presented.

Student JCR: I think the theme about “the existing forms of energy” and “energy transformation” is connected. Because the transformation of energy is actually one existing form of energy change into another form.

Student WQY: I think “the existing forms of energy” connects to “energy producing.” The energy only exists after it is produced.

Student HSJ: I think the theme about “energy producing” connects JCR and WQY’s idea. It has connections to both of these two ideas. The energy produced some way, and then it might transform into another form right away. It might also stays in the same form, like the coal, the energy stays in the coal until people dig it out. Then the energy in the coal is utilized by people, and it might change into another form (Video script to Class A, 11/16/2013).

This discussion could help the students see the ideas in their discussion in a connected way. However, this activity was conducted at the end of the Phase 1 after the students’ portfolio notes were written. In this case the effect of these activities did not reflected in students’ portfolio notes in Phase 1, but could transfer into Phase 2. In Phase 2 when students discussed their ideas, the teacher encouraged them to look for the connections during the discussions. This could also contribute to the improvement of the idea connectedness in students’ individual understandings. For instance, after one student posted a question about “What is biodiversity?” on KF, the teacher (Ms. Lee) build on her question by saying:

This is the central question for this unit, I highly recommend you to focus on this question! To explore on this question, I suggested you to first figure out the relationships among the creatures, the living things and nonliving things, as well as the creatures and the environments. These will provide us multiple perspectives to understand biodiversity (Ms. Lee, Class A, 11/26/2013).

The content differences among the two Phases could also attribute to idea connectedness. Compared with the ideas in the Energy unit, the ideas in The Biodiversity
Unit could be more easily connected. For instance, the students did not realize the connections between the themes about energy transformation and the themes about electromagnets until in final presentation of the Energy Unit. However, in the Biodiversity Unit, the students always referred to the idea of “food chain” to explain the ideas and questions, such as “why did dinosaurs extinct so easily?”, “Why should we protect the rare animals?” “What will happen if there are too many sheep and not enough wolves in the world?” “What will happen if there are no green plants on the earth?” The connections among the ideas in biodiversity could be more easily understood by the students.

Overall the quality of the students’ portfolio notes were improved in Phase 2 (Biodiversity Unit) compare with Phase 1 (Energy Unit). The knowledge diffusion, depth of understanding and connectedness of the ideas were all significantly improved in students’ reflective text. This indicated that the collaborative assessment in Phase 2 played a positive role in students’ personal reflection of the inquiry.

*Is the formative assessment associated with the change in students’ depth of understanding in pre-and post-tests?* A two-way repeated ANOVA was conducted to analyze the depth of understanding in the pre- and post-test in both phases.

Presented in Table 4.5 is a summary of the means and standard deviations for the pre-and post-test scores of the students from two classes on studying in both phases.

*ANCOVA for Phase 1.* An analysis of Covariance (ANCOVA) was conducted to compare the students’ performance in the post-test in Phase 1 with the control of their difference in pre-test. The result indicated that there was no significant difference between the
two classes’ post-test scores after controlling the effect of the pre-test, F(1, 79)=0.11, p>.05.

**ANCOVA for Phase 2.** For the post-test scores in Phase 2, ANCOVA was also conducted to compare the two classes. The result indicated that there was no significant difference between the two classes’ post-test scores after controlling the effect of the pre-test, F(1, 79)=2.51, p>.05.

Table 4.5

*Pre-and Post-test Scores of Two Classes in Two Phases*

<table>
<thead>
<tr>
<th></th>
<th>Class A</th>
<th>Class B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
</tr>
<tr>
<td></td>
<td>M(SD)</td>
<td>M(SD)</td>
</tr>
<tr>
<td>Energy Unit</td>
<td>29.83 (14.62)</td>
<td>43.20 (17.29)</td>
</tr>
<tr>
<td>Biodiversity Unit</td>
<td>26.69 (17.63)</td>
<td>39.76 (15.59)</td>
</tr>
</tbody>
</table>

The results of the analysis indicated that the assessment was not associated with a change in students’ depth-of-understanding performance as measured in the post-tests.

**Conclusion**

The case study of online entries, interviews, class video transcripts and class observation notes revealed how the procedures, activities and tool features made the assessment possible. The data showed four procedures (focus setting, evidence collecting, evidence interpreting, and planning) enabled the community to move progressively toward the assessment goal. The activities and tool features focused on promoting the “out-in-the world existence” of collective knowledge, supporting the collaboration across different social levels, and making the assessment process easier for the community.
The data also revealed that the teachers’ roles in the assessment mainly focused on supporting the students to shoulder their collective responsibility to assess their collective knowledge advances. They facilitated the students to overcome the social and cultural barriers on changing from passive test takers to active assessors; transiting their identities as independent active assessors; and correcting their misconceptions about collective knowledge. They helped the students work as a knowledge building community to sustain their ideas and to refine their conceptual artifacts. They also encouraged the students to take advantage of the technical affordances.

To investigate the roles of the assessment in the student’s after assessment inquiry, students’ online entries, social network pattern, individual student’ portfolios, and their depth-of-understanding performance in the pre-and post-tests in both phases were compared and analyzed. The content analysis of the students’ online entries revealed that the community who conducted the assessment contributed more idea deepening questions and more sophisticated explanations. The assessment helped the community move their discussion from intuitive to sophisticated, from shallow to in-depth.

The SNA analysis of students’ online social positions revealed that the network density and centrality index both increased after assessment. The content analysis of students’ individual portfolios showed that the quality of their reflective text was significantly improved in Phase 2 in terms of the knowledge diffusion, depth of understanding and idea connectedness. The analysis of students’ pre- and post-test performance showed no significant differences between the two communities either in Phase 1 or Phase 2.
Overall, the results of the data analysis addressed the research questions. The result of case study illustrated how the assessment was adopted and implemented by the community in a specific context. The analysis to the after-assessment online posts, students’ portfolio notes and the pre- and post-test scores revealed how the assessment was associated with student’s online deepening moves and individual understanding development. The detailed interpretations of these analysis results will be presented in next chapter.
Chapter 5: Discussions

This chapter discusses the major findings in relation to the research questions. It highlights contributions of this research to the literature, suggests the implications for educational practice, reflects on the limitations of this research, and makes suggestions for future research.

How Do Students and Teachers Conduct the Assessment of and for Knowledge Building?

This research question focuses on the implementation of various elements of the assessment designs. The results indicated that the implementation of assessment for community knowledge included four major procedures which were supported by activities and tool features: focus setting, evidence eliciting, evidence interpreting, and planning. The implementation of the assessment of the social dynamics and individual cognition went through slightly different procedures, and the activities and tool features focused on connecting these two attributes with the advancement of the community knowledge (See Table 5.1). Some activities in implementation were different from the design. Details are illustrated below.

Table 5.1

The Design and Implementation of Formative assessment for Knowledge Building

<table>
<thead>
<tr>
<th>Where are we going?</th>
<th>Where are we now?</th>
<th>How to get there?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarifying inquiry intentions and criteria for success</td>
<td>Eliciting evidences for achievement</td>
<td>Interpreting evidences</td>
</tr>
<tr>
<td>Community</td>
<td>(Design)</td>
<td>(Design) Collaboratively</td>
</tr>
<tr>
<td>Knowledge</td>
<td>Collaboratively define the goals emerging from the knowledge building practice</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Implementation) The community collaboratively defined the focus of the past instead of goals for future.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Criteria for success were not discussed.</td>
<td></td>
</tr>
<tr>
<td>Social dynamics changes</td>
<td>(Design) Teachers defined the goals of social dynamic change as high degree of participation and distributed engagement</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Design) The SNA tools automatically collect the social network data and generate SNA charts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Implementation) ITM automatically display the community’s social behavior pattern in the context of idea development trajectory</td>
<td></td>
</tr>
<tr>
<td>Development of individual understanding</td>
<td>(Design) Individually define the emergent goals of personal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Design) Individually write portfolio notes to reflect on the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Design) Individually find out the progress and challenges in personal understanding</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Design) Individually make plans to indicate their potential</td>
<td></td>
</tr>
<tr>
<td>understanding and the connections between personal understanding and community knowledge (Implementation)</td>
<td>individual understanding developments and the connections between the individual and community knowledge advancement (Implementation)</td>
<td>contributions to the community in the next step inquiry (Implementation)</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>The goals of individual understanding were not defined.*</td>
<td>“Which part I would like to reach further” is decided here based on the understanding of current status and emerging deeper goals.</td>
<td>Plans were made to balance “how I can reach further” and “how we can reach further.”</td>
</tr>
</tbody>
</table>

| The students keep records of their achievement in every class | “Which part I would like to reach further” is decided here based on the understanding of current status and emerging deeper goals. |

**Note.** The words in blue font describe the differences between the design and the implementation.

**Focus setting: clarifying inquiry intentions and criteria for success.** When assessing the community knowledge advancement, the students first individually looked at their previous discussions to find their high interest themes of inquiry. After that they generated a “theme list” in their personal notebooks, and then proposed their themes to the community. The community reviewed and synthesized the individual proposals to generate a collective theme list as the focus of the assessment.

In this study the inquiry intentions (the goals) for community knowledge advancement were not predefined by the teachers nor the community members. Instead, they emerged from the discussions. As discussed in Chapter 2, the advancement process of community knowledge is a sustained, unfolded progress within which the goals are emergent instead of fixed (Scardamalia & Bereiter, 2006; Zhang et al., 2009). In this case what the community defined in this procedure was not the goals to specify “where we are going,” but the focuses
(the high interest discussion centers) that emerged from their previous knowledge building practice. These focuses framed the direction for later detailed evidence collecting.

The “big ideas list” achieved its “out-in-the-world” existence in the public space through an individual proposal followed by class discussions. This list captured the basic structure of the community’s collective knowledge and framed the scope of their reflection in evidence collecting. However, the criteria for the success of community knowledge advancement were not determined at this stage. The teacher did not engineer activities for this issue, and students did not know the desired quality of the conceptual artifacts for assessment. The discussions about the criteria issues emerged in the later procedures based on the community’s real needs.

Similar to the assessment of and for community knowledge advancement, the goals for assessing students’ personal understanding were not determined by the teachers, or specified at the beginning of the assessment either. Instead, they emerged after the students understood “where I am now.”

The only exception is the assessment of and for social dynamics change. The goal for social dynamics development was made clear by the teacher at the beginning of the assessment: the desired social network pattern should have dense interaction and distributed engagement. However, these pre-defined goals (high degree of participation and distributed engagement) might not have represented the real needs of the knowledge building community. For instance, the engagement might not necessarily have to be evenly distributed; some students could tend to post very limited, but very valuable ideas, and some students might
tend to post many posts with superficial content. The students could also play various roles in different topics. Some students could be the discussion leaders about the new energy vehicles since they are very familiar with the vehicles; some students could be the leaders in a discussion about the electromagnets experiments due to their interest in hands-on activities. The goals of social dynamics have to adapt to the needs of the development of the local knowledge building community.

**Evidence eliciting: collecting detailed evidence for achievements.** When assessing community knowledge advancement, the students formed groups each of which used ITM (Idea Thread Mapper) to create an “idea thread” with the “big ideas list” as the frame and guidance. They identified important online discussion notes for each theme, which were displayed by ITM as an “idea thread” representing the idea trajectory of the theme. These threads were further edited (removing unrelated notes, adding notes that were omitted by the search engine, highlighting key notes) through group discussion. Each group then collectively created a “Journey of Thinking” synthesis as a reflective textual representation of the idea development of the theme. The community also reflected on “what we can do with our collective knowledge” through conducting an authentic problem solving task (design the ecosystem for the Moon Base).

As discussed in Chapter 2, the conceptual artifacts needs to achieve their “out-in-the-world” existence in the public space in order for the students to work on community knowledge (Scardamalia & Bereiter, 2006; Scardamalia & Bereiter, 2010). The activities and tool features for assessing community knowledge advancement focused on
enabling the community to create graphical, textual and statistical representations of their community knowledge advancement. Creating and refining these conceptual artifacts (idea threads, idea thread map and “Journey of Thinking” syntheses) supported the community’s search for detailed, in-depth understanding of the trajectory of theme development. Sorting and reviewing the notes helped the students find the notes that they have never read before, comprehend the contributions in a temporal context, build connections between their current inquiry and previous ideas, and find out which notes could be valuable and needed by the community. Perhaps because the criteria for success were not discussed in the previous procedure, the quality of students’ conceptual artifacts tended to be low. This problem was detected by the teachers and brought to the community. The community then built the criteria for the conceptual artifacts through class discussions, which contributed to the improvement of the meta-conceptual artifacts.

When assessing social dynamics change, the evidence collecting was not conducted by the students. Instead, the SNA tools embedded in KF automatically collected the social network data and generated SNA charts. The teachers and students found they also needed evidence to illustrate how their social behaviors connected with community knowledge advancement. In this case students’ participation on certain themes was added as evidence of students’ social dynamic change in Phase 2. This was automatically generated by the ITM tool and displayed on idea thread map.

When assessing individual cognition development, the students recorded their gains in their portfolio notes, and then in assessment session they wrote reflective texts to summarize
their overall individual achievements. As discussed in Chapter 2 individual students’
cognition is the starting and ending points of the community knowledge (Stahl, 2006). The
activities and tool features focused on building a “macro-micro” connection between
community knowledge and individual understanding (Zhang et al., 2009). In this case the
teachers’ scaffolds for reflective texts focused on guiding the students to both reflect on the
trajectory of individual development, and connect their individual cognition with community
knowledge. For instance, when writing “How my ideas are improved,” the students stated
how their individual ideas are developed through reading other’s notes or discussing with
others. When writing “My ‘aha’ moments or the notes that really inspired my thoughts”, the
students also state how other people’s ideas contribute to their individual idea development.
Writing reflective texts in portfolio notes enabled the students to find out “where I am now”
in the context of the community knowledge advancement.

Evidence interpreting: inferring current inquiry status and identifying deeper
goals. For community knowledge advancement, the students first reflected on the trajectory
of each idea thread in groups, and interpreted idea development achievements in the “Journey
of Thinking” texts. Then the students and teacher collaboratively reflected on community
knowledge advancement across themes supported by the map of idea threads projected on a
screen. The community used the textbook as a reference to check idea coverage (what
important idea haven’t been discussed), and discussed the challenges for further deepening
the existing ideas. By examining their current achievement with their envisioned progress,
they identified gaps and challenges that needed to be addressed to deepen their inquiry. In the
discussion after conducting authentic problem-solving tasks, the students also reflected on the challenges in their current knowledge status.

In this procedure, the activities and tool features enabled the community to generate three types of metacognitive artifacts to help present and interpret their community knowledge progress: interpretations of the idea threads, idea thread maps, and their performance in authentic problem solving tasks. Creating these metacognitive artifacts required students’ high order thinking (including comparing analyzing, evaluating, and creating) based on existing conceptual artifacts (idea thread, idea thread maps, and “Journey of Thinking” syntheses) and invited the whole community’s collaboration. These activities were intended to help the students see the big picture of the current status of their collective knowledge, which provided a basis for identifying the gaps and challenges of their current status. The community also identified deeper goals or sub-goals emerging from the idea development progress; these goals turned into possible directions for future inquiry. This also reflected the emergent nature of the idea development in knowledge building; what became important was where we could go from here, not where we are destined to go.

For social dynamics change, the students collectively interpreted the SNA charts on KF in Phase 1. The teachers felt this activity did not effectively increase students’ activeness on participation because it did not provide the executable feedback on addressing the social dynamic problems to many students. In Phase 2, the teacher created SNA reports and provided suggestions for improving the community’s social behaviors. The community also interpreted the note distribution on ITM to infer their social behaviors change in the context
of idea development.

To the students, interpreting the social network charts is a method to get information about individual social positions (am I actively contributing and connecting to others?) as well as the community’s social network status (is the community active contributing and distributed connecting?). This allowed the students to see the connections between individual social position and the community’s overall social dynamic performance. It also enabled the students to make their decisions on social behaviors from “non-reflective” or “socially driven” to “information driven” (Baker–Doyle & Yoon, 2011). However, there was gap between “I know I need to do more” and “I know how to do more.” As Black and Wilam (2009) emphasized, the feedback functioned formatively only if the information was used by the learner in improving performance. The feedback about students’ social network performance was not sufficient to guide their improvement in their online participation of community knowledge building. In this case, the feedback based on the note distribution on ITM was used to fill this gap: it helped the students understand what part needs more contribution, which connected students’ social behaviors and specific actions for contributing to the community knowledge.

For individual cognition development, writing reflective texts is both an evidence collecting and evidence interpreting process. By reflecting on their cognitive development progress the students identified their current knowledge status and challenges. Possible deeper goals emerged from the interpretation, which informed the students “which part worth to reach further.”
Feedback providing: Planning for the deeper goals. Based on the current status of knowledge work reviewed, the community made two types of plans for their further knowledge building practice: in groups they planned for deeper work needed in each idea thread; and as a whole class they made plans for their whole inquiry initiative. The activities and tool features were designed to scaffold students’ idea reviewing and co-planning, and provide public spaces for displaying and sharing the plans.

In the “evidence interpreting” procedure the community identified “where we are” and “where we could go,” and after that they needed to establish “how we could go further.” Making plans for further inquiry is a high-level metacognitive process based on the gaps and challenges the community identified. It demanded the community analyze the gaps between the current knowledge status and the emergent deeper goals or sub-goals, and find out the ways to address these gaps. The challenge is that since the idea development in knowledge building is an unfolding process, it was impossible for the community to envision what goals and focuses could come out of the future discussions. In this case what they made is not a concrete blue print with detailed steps to reach fixed goals, but a plan to address the possible methods and resources that support them to reach one or two steps further from their current status.

For social dynamics change, the students made plans about how to improve their social behaviors. The interpretation of SNA charts told students whether the community was actively interacting, and who the active participants were. The idea thread map illustrated which themes needed further discussion. This supported the students to make an executable
plan on their social dynamics change.

For the individual cognitive development, students made plans in their portfolio notes on how to advance their personal understanding based on the emerging deeper goals identified. Similar to the community knowledge advancement plan, the individual students’ plan addressed possible ways to reach emerging deeper goals from current status instead of reach pre-defined goals. To strengthen the “macro-micro” connections between the individual and community cognition in knowledge building practice, the scaffold from the teachers guided the students to consider the needs of community knowledge advancement when making their personal plans.

In essence, the implementation of the assessment was an interaction between the assessment design and practice. The pre-designed procedures, activities and tool features were contextualized by the members of a community, and some activities and tool feature utilization emerged based on the need in practice. Through creating a set of conceptual artifacts, the community established “where we are” through collecting and interpreting the evidence and deciding “where we are going” based on the comparison of the current knowledge status and the emerging goals. A plan is then generated to address “how to reach further.” The feedback of the assessment of community knowledge, social dynamics and individual understanding was used to inform the next-step knowledge building practice.

The assessment also leveraged students’ collective responsibility to create and refine a series of metacognitive artifacts (including “big idea list,” “idea threads” and “idea thread map” “systematic interpretations” and “group and class plans,” etc.) through a sustained idea
development process. The activities and tool features focused on promoting the “out-in-the-world” existence of the collective knowledge and supporting the collaboration among the students, so that the community could collaboratively take emergent understanding to extend or synthesize other people’s thoughts.

**Teachers’ roles in the assessment implementation.** Data analysis showed that in the current assessment, the teachers’ roles focused on supporting the students to take collective responsibility as a team of active assessors. The teachers fulfilled these supporting roles in following aspects:

**Supporting students on adopting their roles as active assessors.** In the current study the assessment was designed to be student-directed; and the students were expected to be in charge of making high-level decisions in the assessment. This included: setting goals, reflecting on progress, and long range planning (Scardamalia, 2002). To fulfill this role they needed teachers’ support and guidance to overcome the cultural and conceptual barriers, including their long-term experiences of being passive test-takers and the competitive tradition among the individual students and groups. The teachers provided cognitive and progressive scaffolds to help the students make important decisions, such as what should be assessed, based on what evidence, and what actions should be planned based on the results. They also invited the students to find solutions to the challenges through discussions (such as students’ working for competing instead of collaboration).

**Supporting students on building criteria for quality assessment work.** In Wiliam and Thompson’s (2009) framework, the criteria for success should be made clear at the
beginning of the assessment. However, in this study the teacher did not discuss the criteria with the students at the beginning. The students did not know the criteria for accurate evidence, reasonable feedback, and an appropriate plan. To increase the quality of the metacognitive artifacts the teachers helped the students realize the quality problems in their metacognitive artifacts, and then guided them with building the criteria through discussions. The criteria were not imposed by the teachers: it was the real needs of the community and it was created by the community. For the students this was another way to take control of the assessment and to realize their collective responsibility: by making criteria together they formulated the standard of the quality of the feedback, and higher quality feedback could better guide their planning (Black & Wiliam, 2009). The criteria were continually improved along with the knowledge building practice, and the students spent much less time discussing criteria issues in the later assessment process.

**Supporting information flow and idea development across different social levels.**

The assessment for knowledge building generated a complex information flow among different social levels, including individual students, small students groups, and the whole class. This information flow formulated a knowledge building process in which different social levels participated in idea generating, idea sharing, idea reviewing, and idea synthesizing progress. The community needed the teachers’ support to manage this complex information flow and idea development process, through which all the community members’ effort could be put together to generate and improve their metacognitive artifacts. The teachers used many methods to support students’ knowledge building actions in the
assessment, including exhausting diverse perspectives of the students and encouraging the students to challenge or build on to each other. They also provided their own thoughts or provoking questions as scaffolds to help the students break their cognition limits for synthesizing or deepening these ideas.

**Supporting students to take advantage of technological affordances.** The current technology provided many affordances to enable the community to conduct the assessment for knowledge building. As the active assessors the students were supposed take advantage of these technologies (van Atlast & Chan, 2007), and this required them to understand why the tools were needed, when the tool should be used, and how the tools could be used appropriately. In this study the teachers focused on stimulating the students’ epistemic needs of using the tools since they considered students’ motivation as the key to the usage of the tools. The teachers provided some examples to help students understand the basic procedures and functions of the tools, but left many technical details for the students to explore. The teachers also encourage help or tip sharing among the students based on their deep trust of the students’ technical potentials as natives of the information age.

In sum the teachers’ roles in this study focused on making the assessment a student-directed collaborative assessment. As discussed in Chapter 2, this assessment was a social process in which community members collaborate and contribute to their assessment work (Scardamalia & Bereiter, 2006; Scadamalia et al., 2012; Zhang et al., 2009). It was also a knowledge building process which required all of the community members' commitment to achieve consensus through metacognitive discourse (Zhang et al., 2009; Zhang et al., 2013).
The students were supposed to take control of the assessment. They needed to overcome a series of cognitive and social challenges including transform their identity from passive test-takers to active assessors, and see the goal of assessment work as contributing to the community’s interest instead of competing with other people. They also needed to build the criteria of the assessment work and understand why, when and how the technology tools should be used. These all needed substantial guidance and support from the teachers. The teachers needed to work as sensitive observers to identify the students’ difficulties and challenges. Based on their observations they decided what kind of support was necessary, and to what level the guidance should be provided. They needed to be flexible supporters to adjust their roles to the interaction of the assessment design, the local pedagogical context, and students’ emerging cognitive needs.

**Is the Assessment of and for Knowledge Building Associated with the Advancement of the Community's Inquiry? If yes, in What Ways?**

The second research question investigated the association between the assessments with community’s after-assessment inquiry advancement. This focused on the quality change of the students’ online posts, social dynamics change, and personal cognition development. The results indicated that the assessment design had certain positive association with above aspects.

**The association of the assessment with the quality of community’s after-assessment online discourse.** To investigate the association of the assessment with students’ after-assessment inquiry, this study compared the change of the distribution of the
KF notes’ contribution types before and after assessment in both classes within the two phases. Content analysis to the contribution types of the students’ online discussion indicated that in Phase 1 when Class A conducted formative assessment and Class B did not, after the first formative assessment session the students of Class A were moving toward a higher cognitive level in their inquiry through contributing more idea deepening questions and refined/sophisticated explanations, while Class B students kept posting factual questions and intuitive explanations. In Phase 2 when both communities conducted refined formative assessment, they experienced similar contribution type change as Class A did in Phase 1. The results suggested that the formative assessment could be positively associated with the quality improvement of students’ online contributions.

The positive association between the assessment and community’s after-assessment contribution quality could be attributed to the formative nature of the assessment. As discussed in Chapter 2, the assessment should provide ongoing feedback to guide sustained idea improvement (Zhang et al., 2009, Zhang et al., 2013). The feedback informed the students which ideas needed to be improved as well as how these ideas could be continually improved. The group plan informed the community how to further advance each theme, and the class plan advised the community how to improve their overall inquiry. The individual students’ plans directed them how to connect their individual interest, strength and resources with the community’s need. The students could also be more motivated to seek higher-level conceptualizations to give them explanatory power over existing or new ideas (Zhang et al., 2007). Moreover, the assessment activities, including reviewing notes for constructing idea
threads and writing plans for thread development, also informed the students which contributions could be needed to forward current inquiry, and what specifically constitutes a valuable contribution. These could help the students change their contribution from superficial, intuitive ideas to more scientific and in-depth ideas.

The association of the assessment with students’ social dynamics change. To investigate the association between the assessments and the change of the students’ social dynamics, SNA analysis was conducted to analyze students’ activeness of participation and distribution of engagement in their online discussion. The results showed that the community who conducted an assessment got a higher increase of its network density when compared with the community who did not. In Phase 2 when the communities both conducted the assessment, the increase of network density became very close between the two communities. This indicated that the assessments could have a positive association with students’ activeness of participation in their latter online discussions. The analysis of the centrality index showed that with or without the assessment, the centrality index increased along with the inquiry process. The community who conducted the assessment got an even bigger increase on its centrality index. This indicated that although overall interaction increased, the students’ engagement (both sending out links and receiving links) became more centralized instead of distributed with time.

The increase of the community’s activeness in interacting could be attributed to the teachers’ encouragement of students’ participation. It could be also attributed to the feedback the students got from assessing their social network status. As stated in Chapter 4 some
students, especially some high achievers, planned to improve their social behaviors based on the feedback from interpreting social network charts; while some students got feedback which connected their social behavior with their cognitive actions. These could all potentially help the students to improve their active levels of participation.

The issue of the distribution of engagement was not clearly addressed in the feedback. Even when it was addressed in the feedback, it was not useful to the community: the students could improve their own social behaviors, but they could not control other people’s actions. Moreover, in the knowledge building practice the engagement of the students could be influenced by many factors, including students’ different interests of the topics, how the ideas developed, and how the inquiry activities were engineered. How to use the assessment to inform a more distributed interaction remained a question.

The association of the assessment with students’ individual cognition development. In this study how the assessment related with the students’ individual cognition development was investigated from two aspects: how it was associated with the quality of students’ reflective text in their portfolios, and how it connected with students’ performance in pre- and post-tests. The content analysis of students’ portfolio notes showed that the quality of students’ reflective texts significantly increased in Phase 2. The students covered more themes, showed better depth of understanding, and described the themes in a more connected manner. The analysis of the students’ performance in the pre- and post-tests showed that with the control of their differences in pre-test, the communities did not have significant differences in their post-tests in both phases.
Students’ better performance in their portfolio notes in Phase 2 could be attributed to the “macro-micro” connection line between the community knowledge and individual understanding. As stated before the assessment could help the students find the notes they never read, understand the posts in a temporal context, and connect current ideas with previous understandings. The students also identified the width of the idea coverage and depth of the idea development, as well as discussed the connections among the ideas in the assessment activities. These understandings could lay out a stronger common ground of their community knowledge, and this refined common ground could enlarge individual students’ big picture vision, helping them to get more in-depth understanding of the concepts and theories, and support them to build dynamic connections among the concepts and themes.

The other explanation of this phenomenon could be the content difference between the two phases. The students had more pre-knowledge of the content in Phase 2 (Biodiversity Unit) since they had discussed “food chain” in Grade 5. Most of the themes about biodiversity were connected to “food chain” in some ways, and this could bring some positive influence to students’ performance in individual reflective texts. Moreover, the community discussed the criteria of the quality portfolio notes after they created their reflective text in Phase 1. This might bring some positive influence to the quality of students’ portfolio notes in Phase 2. This reveals the limitation of current research; more in-depth studies with the control of the content differences and the time differences are needed in the future.

The result of the analysis of the pre- and post-tests revealed the tension between the
knowledge building practice and the pre-defined tests. The pre- and post-tests were pre-designed by the teachers before the knowledge building was conducted. It is impossible for these tests to fully elicit students’ achievements in the emergent, unfolding idea development process. This echoes with the differences between the social-constructivism and other epistemology discussed in Chapter 2. If knowledge is socially constructed, then the deeper goals or sub-goals of the big topic should be continually identified in the knowledge building practice (Stahl, 2004). These deeper goals cannot be predicted before the dynamic, evolving knowledge building practice happened. In this case the function of these tests for the community was limited on showing the teachers or researchers how far the students were from their pre-defined goals. Whether these pre-defined goals were valuable to the students, and whether the teachers should bring the students back to work on these goals remains questionable. This tension suggested that new assessment methods are highly needed to capture the emergent nature of the idea development in knowledge building practice.

**Putting the Findings Together**

This research describes and analyzes the implementation of a formative assessment design for collaborative knowledge building in a specific context. As discussed in Chapter 2 the assessment needs to capture the advancement of three attributes: community’s collective idea advancement, community’s social dynamics, and the development of individual understanding Scardamalia et al, 2012; Stahl, 2006; van Atlast & Chan, 2007). Formative assessment focusing on these three attributes needs to generate ongoing feedback to guide sustained discourse and idea improvement (Zhang et al., 2009, Zhang et al., 2013). Such
assessment needs to be integrally embedded in students’ knowledge building discourse (Scardamalia et al., 2012), to leverage the key principles of knowledge building, including recognizing students as epistemic agents with collective responsibility, focusing on co-creating conceptual artifacts, and sustained idea development.

Based on these arguments, this study designed a collaborative formative assessment and implemented this assessment in two science classrooms in a Chinese elementary school. The results showed that the existing formative assessment frameworks (Wiliam & Thompson, 2007; Ruiz-Primo & Li, 2013) need to be revised to adapt to the requirement of knowledge building practice. Knowledge building is the production and continual improvement of ideas of value to a community (Scardamalia & Bereiter, 2003), thus the directions of the inquiry could not be pre-defined by the teachers, the third party, or even the students themselves. Instead, deeper/expanded goals should emerge from the knowledge building discourse (Zhang et al., 2009; Zhang et al., 2013). In this case the formative assessment of and for knowledge building cannot be a linear process that generates feedback to inform the students how to move toward certain fixed inquiry goals. Instead, it should be a cycle of continual idea development process, within which the emerging deeper/expanded goals are identified and screened, and the feedback about how to reach further toward these deeper goals continually inform the next-step inquiry (See Figure 5.1).
To be specific, when assessing the community knowledge advancement, the community should not define the goals at the beginning of the assessment. There are no “fixed goals” for the inquiry since knowledge building is an unfolding idea development process (Scardamalia & Bereiter, 2003; Zhang et al., 2009). Instead, the community could define the “focuses” of their previous knowledge building practice, and these focuses could be used to shape more detailed evidence collecting in the next step. The evidence collecting and interpreting could help the community establish “where we are,” and based on this information the community could identify expanded or deeper goals which emerge from the...
inquiry, and then decide “where we are going” through identifying the valuable goals and the gaps and challenges for achieving these goals. They can then generate plans for addressing these gaps and challenges through knowledge building discourse. With these deeper goals as the new direction and the plans as the guidance, the community continues with their idea development progress in their next-step inquiry.

The formative assessment of and for social dynamics change and individual cognition development could go through a similar process. For the social dynamics change, the community could first identify the current status of their social dynamics, and then decide what should be their next-step goals, and how they can achieve these emerging goals. For the individual cognition development, the students first need to define the current status of their individual cognition through evidence collecting and evidence interpreting, then decide “where I could go based on current status”. The feedback should be the result of students’ balancing “how I would like to reach further” with “how we want to reach further” in considering of their limited personal resources.

Among the three major assessment attributes, community knowledge advancement should be the center of the assessment. As discussed in Chapter 2, constructing community knowledge is the main purpose of knowledge building (Bereiter, 2002; Scardamalia & Bereiter, 2003), and the community knowledge is developed through social interaction among the members, and individual cognition is advanced through the interaction with group cognition (Zhang et al., 2009). In this case the deeper /expanded goals that identified in the assessment to the social dynamics change and individual cognition development should serve
the needs of the deeper/expanded goals for community knowledge advancement. The feedback of the social dynamics change needs to be connected to the community knowledge advancement to take its effect, and the feedback of individual cognition development should address the need of community knowledge advancement.

Beside the updated formative assessment design, the implementation of the assessment also suggested that the logic of the reasoning chain in the design of the assessment needs to be tested in the implementation. The assessment design proposed a reasoning chain among the focuses/goals, evidence collecting tasks, evidence interpretation, and feedback: the focuses of the assessment should inform which evidence will be collected, what interpretations will be generated, and then the gaps and challenges identified based on the interpretations direct how the plans will be made. However, the practice showed that some parts of the reasoning chain were broken. For instance, when assessing community knowledge, the lack of the discussion of the criteria for the assessment work caused a quality problem for the conceptual artifacts. When assessing social dynamics change, the feedback did not bring direct guidance to later inquiry actions. These broken or missing parts of the reasoning chain were identified by the community, and they provided the solutions to these broken links in the process. For instance, after realizing the criteria issue, the community collaboratively built criteria through discussion. When finding the gap between the feedback of social dynamics and their actual participating behaviors, the teachers and students added the feedback based on idea thread map to connect their social behaviors to the community knowledge advancement. This showed the benefit of leveraging knowledge building as the
assessment form: when students took collective responsibility on creating and advancing the metacognitive conceptual artifacts, they had the potential to identify emergent problems and fixed them along the way.

The implementation of the assessment also revealed that the feedback could be positively associated with the improvement of students’ knowledge building discourse and individual understanding. When assessing community knowledge advancement, the evidence collecting process and the feedback about directions and methods of improving their inquiry could inform the students which initiations are needed most and the criteria of quality contributions. This could support the community to contribute higher quality notes in the most needed areas. The feedback about the social dynamics change could help the students understand the connection between social dynamics and cognitive developments. This social awareness of the commitment to advance the community’s knowledge could help the students participate with better knowledge of which theme needs more contribution. Meanwhile, with the feedback on the most needed areas of contributions, students may tend to focus on a few topics in their discourse, leading to more centralized interaction after assessment surrounding a few members who specialized in these areas.

Moreover, formative assessment strengthened the “macro-micro” connections through scaffolding students’ connected their individual understanding developments (both the achievements and emerging goals) with community knowledge advancement. In the formative assessment students achieved deeper understanding of their community knowledge,
and this could contributed to the improvement of knowledge diffusion, depth of understanding, and idea connectedness in students’ individual cognition.

The roles of the teachers in the formative assessment for knowledge building were not clearly stated in the assessment design. Instead, they emerged from the implementation practice. The design emphasized students’ epistemic agency and collective responsibility to define the assessment goals, manage the process, and utilize the assessment results. The teachers’ roles focused on supporting the students to overcome the challenges and barriers to take their responsibilities. This required the teachers to have deep trust in the students’ potential on fulfilling challenging roles in the assessment process, work as sensitive observers to identify the students’ difficulties and challenges, and provide necessary support and guidance based on students’ real needs. Moreover, the teachers also worked as the critical adopter of the assessment design. They found the problems and broken links in the reasoning chain, and tried to encourage the students to find the solutions through knowledge building discourse. They were also important sources for the refinement of the formative assessment of knowledge building. Their participants’ first-hand experiences and suggestions guided the refinement of the assessment design.

In general this study provided a detailed account of how an assessment for knowledge building should be designed and implemented in a specific context. The major contribution of this study is connecting the formative assessment literature with knowledge building literature. It is the first attempt to adopt a formative assessment framework for the purpose of assessing knowledge building practice. Based on the formative assessment framework this
study designed separate assessment activities for three major attributes of knowledge building: community knowledge, social dynamics, and individual understanding development. The reasoning chains that connected these assessment activities were assumed in the design, and then tested in the implementation process. To the CSCL researchers this study showed how the community knowledge (group cognition) could be assessed by the students with the support of the technical affordances in a blended learning environment, and how the social dynamics and individual cognition interacts with the community knowledge in the assessment. It suggested that the feedback of the formative assessment could guide the group to monitor and revise their sustained idea development progress, and the formative assessment process can be part of knowledge building practice in which conceptual artifacts are created and continually sustained. To the researchers focused on formative assessment, this study showed the major discrepancy between the formative assessment framework and knowledge building. The existing formative assessment framework set the goals as pre-defined, while knowledge building viewed the goals as emergent. The assessment for knowledge building needs to provide feedback to direct the immediate next step inquiry in the large picture of long-term outcomes, not a plan toward pre-defined goals.

**Implications for Educational Practice**

The context of the formative assessment in this study was the knowledge building process in the two science class-rooms in a Chinese elementary school. To the education practitioners who work in a similar context, this study provided an example of how the formative assessment could be embedded in the knowledge building practice. It suggested
that students’ epistemic agency and collective responsibility should be emphasized through allowing them to define the assessment focuses, collect the evidence, interpret the evidence, and generate feedback. It also required the community to capture the development of three major attributes: community knowledge advancement, social dynamics change, and individual cognition development. The community knowledge advancement could be assessed by the community collaboratively creating and developing a series of conceptual artifacts (including idea threads, idea thread map, and “Journey of Thinking” syntheses) with the support of the technical tools (ITM). The assessment of and for social dynamics change could also leverage the SNA tools and ITM to collect and interpret the evidence. For the individual cognition development, having students write reflective texts in portfolio notes with proper scaffolds could be a possible way to elicit the evidence and generate feedback.

This study also suggested that among the assessments of and for the three major attributes, the assessment of and for community knowledge is the most challenging. The creation of conceptual artifacts is a high level meta-cognitive process, and the information flow among the individual students, groups and the whole community is very complex. This required the students to overcome the cultural and conceptual barriers, including their long-term experiences of being passive test-takers and the competitive tradition among the individual students and groups. It requires the teachers to provide sufficient support to the students and manage the complex information flow and idea development process, so that the community members’ effort could be put together to generate and improve their metacognitive artifacts.
This study revealed that with sufficient guidance and support, the students were able to take responsibilities for making important decisions, building the criteria for success and conducting the assessment activities. This encouraged the teachers to switch their roles from “instructing” to “supporting” in the assessment, and to give deep trust to the students’ capabilities and potentials. Although what support is needed from the teachers, and to what level the guidance should be provided to the students could be vary in different communities, the teachers’ measures on fulfilling their supporting roles in this study could still be used as reference for the practitioners in other educational contexts. It suggested the teachers work as both sensitive observers of students’ social, cultural, cognitive status, and flexible supporters to adjust to the students’ emerging needs.

The study also suggested that these students could work as the active users of the technical analysis tools (including the SNA tools embedded in KF and ITM tools). The key for the students’ success on using these tools was not mastering the detailed functions, but their epistemic need for using these tools, and their understanding of when and how the tools could be used appropriately. The teachers should stimulate the students’ epistemic needs for using the technical tools, and leave the technical details to the students- the information and technology natives-to explore.

Moreover, this study also showed that the formative assessment for knowledge building could have some association with the improvement of the community’s after-assessment contribution quality, overall community’s activeness in online participation, as well as idea diffusion, depth of understanding, and idea connectedness shown in individual
portfolio notes. This may encourage the practitioners to join in the practice of formative assessment for knowledge building, and discover more possibilities of leveraging knowledge building in the assessment. It also suggested that although involving students as the assessor could take more time and effort when compared with teacher directed or third-party imposed tests, the efficiency could be improved when the students became familiar with the procedures, criteria and the technical tools. This encouraged the practitioners to give deep trust for the formative assessment and students’ potentials as active assessors, and have the patience to wait for students’ social and cognitive development. The limitations of the assessment, such as the tension between the pre-defined assessment and the emergent nature of the discussion focuses, encouraged the practitioners to modify the assessments to adapt to the need of knowledge building in their own contexts.

To the educators in other contexts, this study could be used as reference for designing and implementing their own formative assessment. First, it revealed that with sufficient support and guidance, the six-grade elementary school students could conduct formative assessment of and for their science inquiry with success. This suggested that other communities in similar or higher grades could also conduct formative assessment of and for knowledge building. Second, the formative assessment in this study is for science inquiry. How the formative assessment works in other disciplinary area was not tested, and it calls for careful refinement based on the needs of specific content. Third, the knowledge building in the current study is a blended learning practice: the students constructed their community knowledge both in the online space (KF) and in their face-to-face discussions. To the
community who works only online or face-to-face, the forms and the methods of generating conceptual artifacts need to be revised accordingly. For instance, to the online discussing only community, they need to generate the conceptual artifacts through online collaboration; to the face-to-face only communities, the community knowledge has different existing forms (not as online posts, but as the paper posts or posters, or mental consensus), and this requires different methods of collecting and interpreting the evidence. Last but not least, the formative assessment is conducted in a relatively long term knowledge building practice (each phase lasted for over six weeks). The assessment of and for the three major attributes in current study was a complex process that took a lot of time and effort (five to six class hours for each phase). To make it work for the short-term inquiry, the assessment might need substantial refinement or completely new designs.

It is worth noting that when revising the assessment design for specific context, the educators need to keep the essence of the formative assessment of and for knowledge building. The assessment activities, the conceptual artifacts, and the tool affordances could vary in different educational contexts, but the focus of the assessment should be on three major attributes: community knowledge advancement, social dynamics change, and individual cognition development, with community knowledge at the center. The result of the assessment could be in different forms (online posts, posters, oral agreement), and it should capture the emerging nature of sustained idea development, and be used to inform the community’s next step knowledge building practice. The teachers and students can play different roles in certain assessment activities, but the students need to work as a group of
active assessors to make important decisions, conduct the assessment activities, and utilize the tool affordances. The teachers should provide support and guidance based on the students’ needs.

**Limitation of the Study**

The first limitation of this study was that the two communities (Class A and Class B) were not randomly assigned due to the restrictions of local school context. Usually Chinese elementary school students remain in the same class for the entire elementary school time (six years), and it is not practical for one school to pick up 80 students, mix them together and randomly assign them into two new classes. In this case the design based research picked two classes as the participants due to the similarity of demographics and performance on previous exams. Still, it is inevitable that some traits of these two classes could influence the knowledge building process and the quality of their assessment products. For instance, some students in Class A tended to bring out deep questions which always move the inquiries to the next level, but they were not actively participating in the class discussions. Usually they did not have very good relationships with their group members in collaborative activities. The students in Class B liked to participate in the class discussions, but the general depth of their thoughts could not match Class A students’ ideas. In this case the comparison these two community’s performance might not be able to rule out the possibility that some differences between the two communities may be attributed to the initial differences among the two classes.

Moreover, the contexts for conducting the assessment activities in the two classes
were not exactly the same. For instance, both classes took the post-test of the bio-diversity unit at the end of the semester. As the teacher admitted, the students were taking many preparation tests before the final math and Chinese exams in that time period. For the Class B students, their post-test was conducted before a math preparation test. Many students were not in the mood for taking the post-test seriously since science is not an “important subject” to them and they were worrying about the upcoming math test. The students of Class A did not have that issue; their post-test was conducted before a music class. How much these differences impacted the students’ performance is unknown.

The second limitation was the time for research. The length of the project and the reviewing time for the Phase 1 assessment design was limited because of both the researcher’s and the school’s tight schedules. This caused a bigger portion of time to be spent on the assessment compared with the whole inquiry time: the students spend over 1/4 of their inquiry time on collaborative assessment. The students have 20 classes for inquiry in one unit, and they spent 5 to 6 classes on collaborative assessment. The time for students to do further inquiry after collaborative assessment was very limited, which could have resulted in the students’ not having enough time to conduct in-depth discussions after the assessment. This revealed the tension between the limited inquiry time and the time consuming knowledge building actions in the assessment, and calls for new assessment design that requires less time.

The tight time schedule also made it impossible for the teachers and students to wait before they started the inquiry in Phase 2. The researcher only got two weeks to roughly go
through the interview data and online discussion data, identify the big issues with the assessment in Phase 1, and refine the assessment design based on the teachers’ and students’ suggestions. This led to the conclusion that there were not too many fundamental changes in the assessment design for Phase 2.

When adopting new technology for the inquiry process, the community’s performance could have also been impacted by the learning curve effect. The students who adopted new technologies or projects might not be able to outperform the one who did not within certain time period. How much the learning curve issue impact students’ performance and how long the learning curve effect lasted in this project are unknown.

The tension between teachers’ traditional pedagogy and the requirement of the assessment activities was also an issue. Although the teachers tried many ways to engage the students to participate into the assessment activities as active agents, sometimes the teachers’ still choose to directly tell the students what to do and focused too much on curriculum coverage. They were “pulled back” by their traditional pedagogy and felt frustrated when the discussion did not go very well. The large class size (over 40 students in one classroom) also challenged the teachers’ ability to keep discipline and encourage students’ participation at the same time. They needed a great deal of professional support to get deep understanding of the assessment theories and assessment designs, develop activities tool features as needed, and decide their proper roles to deal with the emerging challenges within the process. However, the relentless teaching schedule for teaching (they were teaching several other classes) made it difficult for them to have enough in-depth discussions with the researcher on these issues.
This caused some activities (such as class discussions) to not be conducted with the desired quality.

**Future Directions**

This study was just a start on designing and implementing collaborative formative assessment in practice. The first attempt at designing and implementing was very preliminary, and the refined design in Phase 2 was also a hasty product due to the intense school schedule. More carefully designed assessments for and as knowledge building are needed to be tested in different school contexts, and the conceptual framework needed to be improved theoretically based on further investigations.

This research brought out the tension between the limited inquiry time and the time-consuming knowledge building based assessment. Leveraging knowledge building in the assessment may have played some positive roles community’s after-assessment inquiry, but how the assessment could have been implemented efficiently to save time for more in-depth inquiry was a challenge. In the interview one teacher suggested that the assessment could be more “embedded and concurrent” in the inquiry process. The students could create idea threads at the beginning of their inquiry, and keep updating and refining the threads as the discussion progressed. The students could refer to the idea threads and idea thread maps to make their inquiry discussions, and the independent assessment sessions could have been greatly shortened. This suggestion could be one possible way to solve the problem, and this method with other possible methods could be designed and tested in the future research.

This research was implemented in a very specific cultural context, and this specific
cultural context played very important roles in the final findings about the use and function of the assessment design. However, due to the limit of the research time, the cultural issues were not fully investigated and discussed. More in-depth research could be conducted to provide a richer description of the cultural phenomenon in the assessment process. The formative assessment for knowledge building could have been implemented in different social and cultural contexts on different subjects, and the researchers could have investigated how the local contexts influence the design and the implementation of the assessments. On the other hand, new assessment activities and technologies may also bring influence to the local learning culture (Zhang, 2010). Future research could focus on the micro and macro cultural change that was brought by the assessment and investigate the details of the experience of the teachers and students in this cultural change process.

In this study the results focused mostly on the community’s achievement, and assessing community knowledge advancement has been a complex and time consuming process. How to make the assessment of and for community knowledge easier to conduct, and what technical affordance can better support this process remains a question. This calls for more in-depth research and technical tools development. Social dynamics and individual achievements were also discussed in this study, but the analysis of this data basically focused on the pre-defined goals (network density and engagement distribution). More in-depth investigation could be conducted on the social dynamics, such as how other social network indicators should be traced based on the emerging needs of the community, and how the interaction patterns changed in the latter inquiry. How the collaborative formative assessment
impact individual students could also be investigated, focusing on some deep issues such as students’ attitude change, their identity change, and their collaborative disposition change. Different students’ conceptual change and social position change, especially the low achieving students’ experiences in the assessment activities should also be studied. Moreover, the tension between the pre-defined tests and the emergent nature of idea development in the knowledge building also made it hard to evaluate individual students’ in-depth achievements. Writing portfolio notes is a good way for the students to reflect their cognitive developments, but it is a very subjective method which could not be sufficient to elicit students’ real knowledge status. Future research may explore possible assessment methods to better objectify individual students’ cognitive achievements while catch the emergent, unfolded nature of the idea development in knowledge building.

This study also brought out the importance of teachers’ professional development. The flexible assessment design and implementation required the teachers be sensitive observers and agile adapters to the emergent needs of the community. The teachers also needed to have deep understanding to the theories of knowledge building and formative assessment, the functions of the assessment activities and tool features, as well as the reasoning chain behind the activities. These are all challenges of the teachers’ professional knowledge and capabilities. The teachers could have also experienced significant cultural, pedagogical and psychological challenges in the assessment practice. In this case many questions about teachers’ professional development are worth further investigation, including how the teachers developed their capabilities in the assessment practice, what factors support or impede
their professional development, and how different professional development methods could support the teachers’ professional development.

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Appendices

Appendix A. Interview Protocol for students

Background Information about this Interview: 访谈背景信息

This interview will be conducted as part of the data collection to test the assessment design in knowledge building. The collaborative assessment design will be implemented among a group of Grade 6 students doing scientific inquiry in their respective curriculum areas. The interview will take place at the end of first phase and second phase. This interview will be conducted individually with 20 students (10 from Class A and 10 from Class B) who are recommended by the teacher in a quiet room in the school building. After Phase 1 is completed, 10 students from Class A will be interviewed with the first interview questions. After Phase 2 is completed, these students will be interviewed with follow up questions. Ten Students from Class B will be interviewed with the first interview questions. The conversation will be audio-taped and transcribed. The interview will be conducted as part of the data collection to test the assessment design in knowledge building. The collaborative assessment design will be implemented among a group of Grade 6 students doing scientific inquiry in their respective curriculum areas. The interview will take place at the end of first phase and second phase. This interview will be conducted individually with 20 students (10 from Class A and 10 from Class B) who are recommended by the teacher in a quiet room in the school building. After Phase 1 is completed, 10 students from Class A will be interviewed with the first interview questions. After Phase 2 is completed, these students will be interviewed with follow up questions. Ten Students from Class B will be interviewed with the first interview questions. The conversation will be audio-taped and transcribed.

First Interview Questions

Interviewer: Hi, my name is XXX, and I am a researcher from University at Albany. I want to ask you a few questions about your study of XXX. Your answers and comments will help me to understand how the assessment activities may help you learn better. If there is any question you don’t understand, please tell me. I will explain it to you.

1. Together with your classmates and your teachers, you have done a lot of activities to study the topic of “energy” (or “biodiversity”) since September. For example, you made inquiry plan together, you discussed with your classmates on Knowledge Forum, and you created idea threads in ITM, etc. Do you remember any other activities? If yes, what are they? Among these activities you have carried out, were there any activities help you evaluate and reflect on your learning progress on this topic? If so, what are they? How did they help you? From September you and your teacher and classmates, you have made an inquiry plan together, you have discussed with your classmates on Knowledge Forum, and you have created idea threads in ITM, etc. Can you remember any other activities? If yes, what are they? Among these activities you have carried out, were there any activities that helped you evaluate and reflect on your learning progress on this topic? If so, what are they? How did they help you?

2. As you mentioned (or may remember), the assessment activities includes creating idea threads, interpreting idea thread maps, writing “journey of thinking” posts,
interpreting social network graphs, write individual portfolios and future community inquiry plans. 如同你提到的(或是你记得的)，我们的评价活动包括创建思维脉络，解读思维脉络图谱，写进程反思，查看社交网络图，写个人学习记录以及制订全班下一步探究的计划。

a) Here’s the idea thread map your whole class has created (show the screen of the idea thread map on the screen of a laptop). Which thread(s) was created by your group? (Show the idea thread that the student mentioned on the laptop.) How did you work with your group members to create this/these thread(s)? How did you work together to write the “journey of thinking”? Did you get any helpful information through creating this/these idea threads? If so, what are they? 这些你们全班就这个主题一起创建的“思维脉络网”（在电脑屏幕上展示“思维脉络网”）。这其中哪一条（哪些）思维脉络是你组创建的？（打开学生提到的那条思维脉络）你们是怎样合作写出“思维进程”的？在创建这条思维脉络的过程中你是否得到了有用的信息？如果是的话，有些什么信息呢？

b) Your whole class then created this map of all the idea threads created by you and other groups (show the map of idea threads again). Did you get any useful information or insight through checking this map of idea threads? If so, what are they? 你们组和其它小组一起创建了这个“思维脉络网”（在电脑屏幕上展示“思维脉络网”）。通过查看这个思维脉络网，你是否得到了一些有用的信息或是想法？如果是，有哪些信息和想法呢？

c) Your class also looked at this social network graph (show the student the social network graph on the laptop screen). Do you feel that this graph is helpful for you to reflect on your collaboration? If so, in what ways? 你们全班还一起查看了这个社交网络图（在电脑屏幕上展示“社交网络图”。你觉得这个图能帮助你反思你们的合作么？它是怎样帮助你的？

d) You whole class also worked out an “inquiry plan” together (Show the student the inquiry plan note on Knowledge Forum). Do you think this “inquiry plan” is helpful to your learning in the next steps? In what ways? 你们全班还一起制订了一个“探究计划”（在电脑屏幕上展示知识论坛上的“探究计划”帖子）。你认为这个探究计划对于你下一步的学习有帮助么？有哪些帮助？

e) You yourself has written a portfolio note (show the student the view of portfolio on Knowledge Forum). How did you select the information to be included in your portfolio note? Do you think this portfolio note help your learning and reflection? If so, in what ways? 你自己也写了“成长档案”（在电脑屏幕上展示知识论坛上写“成长档案”的视窗）。你是怎样选择写进“成长档案”里的信息的？你认为这个“成长档案”对你自己的学习和反思有帮助么？如果有，有哪些帮助？

3. Please tell me your impression about the ITM tool. Were there any features you like? If so, why? Were there any features you did not like? If so, why? 请讲讲你对 ITM 这个工具的印象。这个工具中有你喜欢的功能么？如果有，为什么喜欢？有你不喜欢的功能么？为什么不喜欢？

4. I want to your idea about working together with the classmates and teachers in the
assessment activities. Do you think it is necessary to work with others in the assessment activities? If so, why? Did you have any good or bad experience in the collaboration? Can you tell me the story? 我想了解一下你对与班上同学和老师一起进行合作评价的看法。你认为在评价活动中与同学和老师的合作必要么？如果有必要，为什么？在合作中你是否有过一些好的或是不好的经历？你能具体讲一讲相关的故事么？

5. Did you find any difficulties in these assessment activities? If yes, what are they? What makes them difficult? Did you get any help/support from other people? 在这些评价活动中你遇到什么困难了么？这些困难是由什么引起的？你是否得到过别人的帮助？

6. Are there any other suggestions or comments about the assessment? 关于我们的评价反思你还有什么意见和建议么？

Thank you very much for your help! 非常感谢你的帮助！

Follow Up Interview Questions 跟进访谈问题

1. Hi, XXX. In Energy Unit you did many assessment activities, such as creating idea threads, writing journey of thinking, writing your individual portfolios, making class plans through discussions. Now the Biodiversity unit is completed. Could you tell me what different activities you have conducted in this unit? 你好，XXX。上个单元就是能量单元你们一起进行了很多评价活动，比如说一起创建 ITM 嘛，写“思维过程”啦，还有全班一起制定计划等等。这个单元，就是生物多样性这个单元已经结束了。你能告诉我一些在这个单元里你做的不一样的活动么？

2. Did you see any changes in your group work or class discussions? Did you see any differences in your collaborations? Such as the labor division and communication among the group members, any differences? 你们这个单元小组活动和全班讨论有没有什么变化？大家合作有没有什么变化？小组分工，大家互相之间的沟通呢？有没有什么变化？

3. You used ITM in the assessment in this unit as well. Did you get any different ideas to this tool? How do you think about it now? 这个单元你也用了 ITM. 你对它的看法有没有什么变化？你现在用起来觉得感觉怎么样？

4. Could you tell me something that impressed you in the assessment sessions in this unit? Anything special? Could you share your experiences with me? 你能不能告诉我这个单元里发生的让你印象比较深刻的事情？有没有什么特别的事情，你可以给我分享一下？

Thank you very much for your help! 非常感谢你的帮助！

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Appendix B. Interview Protocol for Teachers 教师访谈计划

Background Information about this Interview 访谈背景信息

This interview will be conducted as part of the data collection to test the assessment design in knowledge building. The collaborative assessment design will be implemented among a group of Grade 6 Chinese elementary school students and teachers doing scientific inquiry in their respective curriculum areas. The interview will take place at the end of first and second phase in a quiet room at campus. This interview will be conducted individually with the science teacher and ICT teacher who teach these Grade 5 students. The conversation will be audio-taped and transcribed.

First Interview Questions 初次访谈问题

1. Based on my understanding, this semester you have been engaging in a series of assessment activities for the inquiry of “energy” (or “biodiversity”). For example, you asked the students to create idea threads and write journey of thinking posts in groups, facilitated the students to interpret the idea thread maps, make community inquiry plans with the students, and asked the students to build individual portfolios, etc. Among these assessment activities, do you find any activities different with the ones you have been conducting in your previous teaching experience? What are they? In what ways they are different? 据我了解，这个学期以来你在“能量”（“生物多样性”）的探索活动中开展了一系列的评价活动。比如，你让学生分小组合作创建思维脉络，写进程反思，引导他们解读思维脉络网，制订全班的下一步探究计划，并要求学生写自己的成长档案，等等。在这些评估活动中，有没有有些是你在之前的教学经验中使用过的评价活动不一样的？是哪些活动呢？具体有哪些不同？

2. Among these assessment activities, are there any activities significantly support students’ inquiry? If so, what are they? Which one is contributes the best? In what ways? Are there any activities do not help much with the inquiry? If so, what are they? For what reasons? 在这些评价活动中，有没有活动非常有力地帮助了学生们的探究活动？有哪些？在这些活动中哪一个贡献最大？为什么？有没有活动对于探究没有帮助？如果有，为什么？
3. In these assessment activities, did you experience any role change as a teacher? Did the students' role change accordingly? Can you give me an example about the role change? Do you take these changes as positive ones or negative ones? Why?

4. When using ITM as a tool to support assessment, did you find any features particularly useful? If so, in what ways? Did you find any features that need to be revised or improved? If so, what are they? In what ways?

5. Did you find any difficulties or challenges in implementing the assessment activities? What are they? How did you deal with these difficult issues? Did you find any problems or limitations in the assessment design itself? For instance, do you think the order of the activities should be changed? Do you find any activities should be omitted? Any activities should be added? Can you tell me your reasons?

6. Do you have any further suggestion to improve the collaborative assessment in the future? Are there any other comments you want to add?

Thank you very much for your help!

Follow Up Questions

1. Based on my understanding, you have conducted a series of assessment activities in the Biodiversity Unit with your students. Among these activities, are there any new activities you have never conducted before? How are they different? In these “生物多样性” 的探索活动中，你和学生一起开展了一系列的评价活动。在这些评价活动中，有没有是跟在上一个单元中使用过的评价活动不一样的？是哪些活动呢？具体有哪些不同？

2. Among these new assessment activities, did you see any activity significantly support the students achieve their assessment goals? Why do you think so? Did you find any activities that were not supportive? Why do you say so? 在这些新的评价活动中，有没有活动非常有力地帮助了学生们的实现他们的评价目标？为什么？有没有活动没有帮助？如果有，为什么？

3. In the assessment sessions of this unit, as a teacher did you experience any new role changes? Could you give me an example? Do you take these role changes as
positive or negative? Why? 在这个单元的评价活动中，作为一个老师，你有没有经历新的角色转换？相你能举个例子来说明么？你认为这些角色转换是积极还是消极的？ 为什么？

4. In the implementation of the assessment in this unit, did you experience any new problems and challenges? How did you deal with them? 在这个单元实施这些活动中你是否遇到了新的困难和挑战？有哪些困难和挑战？你是怎样克服这些困难的？

5. Do you think the assessment in this unit is more successful than it is in last unit? If yes, in what ways? 你是否认为这个单元的评价活动比上个单元的评价活动成功？如果是的话，为什么？

6. Do you have any suggestions for future assessment? 关于今后的评价活动你还有什么建议吗？
Appendix C. Related Content in the Chinese National Curriculum for Elementary School Science

总目标 General Purpose

（一）科学知识 Scientific knowledge

学习物质科学、生命科学、地球科学、设计和技术四大领域中浅显的，与日常生活密切相关的知识，尝试解释各种各样跟科学有关的现实生活情景为背景的问题及现象。Seek to understand the basic knowledge of four basic fields of science: physical science, life science, earth science, design and technology. Try to explain the related problems and phenomenon in the everyday life.

1、通过对物质科学相关知识的学习，了解物质的常见性质和基本运动形式，认识物体的运动和力，了解能量具有不同的形式并且能够互相转换。Through studying the knowledge for physical science, students seek to understand the material’s common property and basic forms of motion; understand there is relationship between force and motion; understand that energy exists in many forms, and when these forms change energy is conserved.

2、通过对生命科学有关知识的学习，认识多种生物及它们的种类，了解生命活动的基本特征，生命之间的互相依存关系，认识到人具有高级的脑，使得人成为能够劳动、进行发明和创造的高等动物。Through studying the knowledge for life science, students seek to understand the variety and interdependency of living species and the basic characteristics of living activities. They should also understand the human being’s brain enable us to become higher animals who can work on, invent and create tools.

3、通过对地球与宇宙有关知识的学习，了解地球上可以分为不同的圈层，它们共同构成了人类生存的自然环境，了解太阳与地球、月球的相对运动关系，知道太阳是地球能源的主要供给者，认识人类与地球环境的相互作用，懂得地球是人类唯一家园的道理。Through studying the knowledge for earth and universe, students seek to understand that the earth is composed by different spheres, and these spheres are all complex systems. They should also understand the relative motion system among the sun, the earth, and the moon, know the sun is the major energy provider for the earth, understand the human beings closely interact with the environment on the earth, and know currently earth is the only home for human beings.

4、通过设计和技术方面的学习，知道不同的技术结构具有不同的功能。Through studying the knowledge for design and technology, understand different design structure has different functions.

5、初步认识到人类为了满足认识世界的好奇心而不断地探索着我们生存的世界。我们周围的世界有许多问题需要探索，因而科学的发展是无止境的。了解科学应用到技术中后，由于技术的运用不当会产生一些社会问题。Understand that human beings are constantly exploring this world to fulfill our curiosity. The development of science is never ending. Understand that science and technology may bring negative impacts to our society if they are abused.

（二）科学能力 Scientific Skills

1、能够识别科学性问题，辨识由生活需要而产生的各种技术问题，在回答问题时首先要考虑收集证据。Identify scientific questions and technical problems based on the needs of everyday life. Collect evidence before providing solutions.
2. 能够大胆猜想，有根据地进行假设，根据已有知识与条件进行实验设计，以便能够验证假设。Generate hypothesis based on guesses; design the experiments to testify the hypothesis.

3. 能够通过观察、实验、调查、阅读等多种方式收集可观察和测量的资料。Collect resources from observation, experiments, surveys, and readings.

4. 能够运用表格、统计图表等形式分析整理数据资料。Organize and analyze data through using charts and diagrams.

5. 能够在居于证据的基础上回答关于物体、事件或系统的特性和规律的问题，从自然现象中发现因果关系。Find systematic characteristics or patterns based on the evidences; find the connections among the natural phenomena.

6. 能够调动思维进行理性的思考，参与讨论和辩论，Think with logic, and participate in reasonable discussion and arguments.

7. 了解科学探究使人们认识自然世界、获取科学知识的主要方法之一。Understand that scientific inquiry is the major method for human being to understand the natural world and acquire knowledge.

8. 学会使用各种工具，包括科学研究中需要的工具、仪器，也包括技术工具，运用工具制造产品或解决实际问题。Learn how to use the tools, including the scientific tools, instruments, and technical tools, to solve practical problems.

（三）科学态度 Scientific Attitude

1. 保持对科学以及与科学有关事件的好奇心，具有一定的想象力，敢于创新。Keep the curiosity to science and science-related events; try to be imaginative and creative.

2. 对科学与技术感兴趣，有参与科学和技术事务的愿望，关心科学和技术的发展。Be interested with science and technology, willing to participate in the science and technology related work, care about the development of science and technology.

3. 能够实事求是，尊重证据，基于证据进行判断推理、解决问题和进行质疑。Respect the facts and evidence, use evidences when making judgments, inference, solving problems and raising doubts.

4. 能够与人合作，形成良好的相互尊重的热人际关系，参与到科学小组中共同研究，解决问题。Willing to collaborative with others, respect other people when participating in the scientific inquiry groups.

5. 能够开放地接纳他人的观点，认识到考虑不同科学视角和论点的重要性。Be open-minded to other people’s ideas; understand the importance of having different perspectives.

6. 具有对资源和环境的责任心，对维护环境的可持续性表现出责任感，对个人行为产生的环境和更有意识表现出采取行动保护自然资源的意愿。Have the sense responsibility to natural resources and environment; care about the sustainable development of the environment; willing to take actions to protect the natural resources.

具体目标 Purposes for Specific Topics

三、生命世界 life
"生命世界“的内容标准的确定是要让学生尽可能多地去认识不同种类、不同环境中的生物，进而对多种多样的生物有比较全面的认识。 For the topic of “life”, students will recognize as many as possible species in different categories living in various environments, and then develop a basic sense of the diversity of living species.
1. 多样的生物 Diverse living species
   (1) 多样的生物之一：常见的植物 Diverse plants
       1.1 能说出周围常见植物的名称，并能对常见植物进行简单分类。 Recognize common plants in the local environment, and be able to categorize them based on certain principles.
       1.2 了解当地的植物资源，能意识到植物与人类生活的密切关系。 Understand the relationship between local plants and the human being’s life.
       1.3 了解更多的植物种类，感受植物世界的多姿多彩。 Understand the diversity of plants, and appreciate the variety of plant family.
       1.4 养成爱护花草树木的习惯。 Develop the sense of protecting plants.

(2) 多样的生物之二：常见的动物 Diverse animals
   2.1 知道生活中常见动物的名称。能用不同标准对动物进行分类。 Recognize common animals in the local environment, and be able to categorize them based on certain principles.
   2.2 归纳某一类动物的共同特征。 Describe the common characteristics of a certain category of animals.
   2.3 认识常见动物的几种类型，如昆虫、鱼类、两栖类、爬行类、鸟类、哺乳类。 Recognize the common categories of animals, such as insects, fish, amphibians, reptiles, birds, and mammals.
   2.4 了解更多的动物种类，感受动物世界的纷繁复杂。 Understand the diversity of animals, and appreciate the variety of animal family.
   2.5 认识动物运动方式的多样性。 Understand the variety of animals’ motion forms.
   2.6 了解保护动物特别是保护濒危动物的重要性。 Understand the importance of animal protection, especially the protection of endangered animals.

(3) 生物与环境之二：进化现象 Evolution
   2.1 能解释适者生存、自然选择的含义。 Describe the meaning of Darwin’s idea of the most responsive species survive.
   2.2 能以某类生物为例，阐释生物进化的过程。 Describe the process of evolution through using one species as an example.
   2.3 关注一些和进化有关的有趣问题。 Pay attention to some evolution related phenomenon in everyday life.

四、物质世界 Physical world
"能量的表现形式"部分讨论了声、热、光、电、磁这些物理现象，并使学生知道它们都是能量的不同表现形式，能量可以转换。 For the topic of “Energy Forms”, the students will understand that energy exists in various forms: sound, heat, light, electric, and magnetism. Energy can be transferred from one form to another.
3. 能量的表现形式 Energy Forms
   (5) 能量的表现形式之五：磁现象 Magnetism
       5.1 探究磁铁的方向特性，磁铁的两极，以及磁铁间同极相斥、异极相吸的规律。 Understand that the force of magnet has directions; a magnet has two poles; the same poles repel each other; and opposite poles attract each other.
       5.2 知道电能产生磁，探究影响电磁铁磁性大小的因素，了解电磁铁的应用 Understand that electricity can produce magnetism, know the major factors that
influence the power of magnetic force, understand the applications of electromagnet in practice.

(6)能量的表现形式之六：能量的转换 The Transformation of Energy
6.1 知道任何物体工作时都需要能量，电、光、热、声、磁等都是能量的不同表现形式。Understand all motions need energy to work; sound, heat, light, electric, and magnetism are different forms of energy.
6.2 认识不同形式的能量可以相互转化。Understand that energy can be transferred from one form to another.
Appendix D. Pre and Post- Test for Energy Unit

Test for Energy Unit 小学六年级科学 《能量》单元测试题

School 学校:  
Class 班级:  
Name 姓名:  
Number 学号:  
Score 成绩:  

1. The diagram below shows a pan of boiling water on an electric stove. 下图是在电炉上将一锅水烧开。

![Pan of boiling water](image1)

1) Can you identify the energy forms that are transforming in this process? Write them down. 你能指出在这个烧水的过程中有哪些能量形式的转换吗？请把它们写在下面。

2) List the things you can do to make water boil faster. You don’t need to worry about the money issue. 请列举出你能让水开得更快的措施。不必担心花钱太多的问题。

2. The diagram below shows an aluminum can before and after it was crushed. 下图是一个铝制饮料罐被踩了一脚之前和之后的样子。

![Aluminum can before and after](image2)

1) Is there any energy transformation happens in this crushing process? If yes, please describe them. If no, please specify your reasons. 在饮料罐被踩这个过程中，是否有能量的转换发生？如果有，请描述有什么样的能量发生了转换。如果没有，请说明理由。
2) Old aluminum cans are often recycled to make new ones. State the effects recycling aluminum has on the environment.

3. The diagram shows a dam and an electric power plant built next to a river. The power plant uses the water from the dam to generate electricity. 下图是一个修在河流上的水坝和一个建在河边的发电厂。这个发电厂利用大坝上冲下来的水来发电。

1) Please describe how the energy has been transformed in this process. 请描述在这个过程中能量是如何转换的。

2) Please list at least one positive and one negative impact of this type of power plant on the environment. 请至少列举出这样的发电厂对环境的一项好处，一项坏处。
4. The diagram shows a controlled experiment designed to test how the change of current impact the electromagnetic force. As shown in the diagram, Xiaoming winded a long electric wire on a nail, then used it connect with one dry battery to made a circuit. He used the nail to attract pins and then break the circuit. He recorded the number of pins the nail attracted in the following chart. In the second trail, he used two batteries without changing other things or procedures. In the third trail he used three batteries. 下图是一个对比实验，用来研究电流的大小对电磁铁磁力大小的影响。 如图所示，在第一次实验中，小明用一根长的电线绕在铁钉上，将这根线的两头分别与一节干电池的两极相连形成一个电路。他用这根铁钉去吸引大头针，然后断开电路。他记下了通电时铁钉吸引的大头针的数目。在第二次实验中，小明使用了两节干电池，但没有改变其它条件。在第三次实验中，他使用了三节干电池。下表中就是他记录下的实验结果。

<table>
<thead>
<tr>
<th>Experiments</th>
<th>Changed factors 改变的因素</th>
<th>Results 实验结果</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Try 第一次</td>
<td>Use one new dry battery 用 1节新的干电池</td>
<td>Attract 7 pins 一次可以吸住 7 枚大头针</td>
</tr>
<tr>
<td>Second Try 第二次</td>
<td>Use two new dry batteries 用 2节新的干电池串联起来</td>
<td>Attract 17 pins 一次可以吸住 17 枚大头针</td>
</tr>
<tr>
<td>Third Try 第三次</td>
<td>Use three new dry batteries 用 3节新的干电池串联起来</td>
<td>Attract 26 pins 一次可以吸住 26 枚大头针</td>
</tr>
</tbody>
</table>

1) Identify the independent variable in this experiment. 在上面实验中改变的因素是:

2) Identify two conditions shown in the diagram that are held constant in all three trials. 不改变的因素是:

3) According to the data in the chart, the conclusion for this experiment is:根据记录在表格中的数据，归纳出实验的结论是:

4) Use the same materials, please design a experiment to test another factor that might influence the magnetic force. 使用上面提过的相同材料，请你设计一个实验，来
验证另一个可能影响电磁铁磁力大小的因素。

<table>
<thead>
<tr>
<th>Research question 研究的问题</th>
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</thead>
<tbody>
<tr>
<td>Hypothesis 我们的假设</td>
<td></td>
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<tr>
<td>Changed condition 改变的条件</td>
<td></td>
</tr>
<tr>
<td>Unchanged condition 不改变的条件</td>
<td></td>
</tr>
<tr>
<td>Procedure 实验过程</td>
<td></td>
</tr>
</tbody>
</table>

5. There are many ways to save energy in your everyday life. Please list the things you usually do (or you plan to do) on saving the energy, and state what forms of energy you are saving by taking these measures. 在日常生活中有许多节约能量的方法。请列出你在日常生活中经常使用哪些节约能量的方法，这些措施究竟节约的是哪种能量。

6. Suppose you are the CEO of a Chinese automobile company. Now you plan to spend most of the R&D money on the research of new energy automobiles. What type of new energy automobiles will be your choice? Please state your reasons to persuade the board. 假如你是中国一家汽车工厂的 CEO（执行总裁）。现在你计划将公司大部分的研发费用投入一种新能源汽车上。你会选择哪一种新能源汽车？请写出你的具体理由以便能说服公司董事会。
7. Currently there are many different types of power plants: hydro-power plants, thermal power plants, wind power station, and nuclear power plants. People also put solar photovoltaic power facility on the roof to get power. Among all these power plants, what is the best choice for your hometown? Please state your reasons.

<table>
<thead>
<tr>
<th>Specification Test Form for Energy Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test Items</strong></td>
</tr>
<tr>
<td>In this column insert the standard content that correspondent to the test items</td>
</tr>
<tr>
<td><strong>Item 1</strong></td>
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<td><strong>Item 2</strong></td>
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<td><strong>Item 3</strong></td>
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<td>Item 4</td>
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<td>Item 5</td>
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<td>Item 6</td>
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<td>Item 7</td>
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</table>
Appendix E. Pre-and Post-tests for Biodiversity Unit

Test for Biodiversity Unit 小学六年级科学《生物多样性》单元测试题

School 学校: Class 班级: Name 姓名: Number 学号: Score 成绩:

1. The graph below shows information about several animals. 下图显示了一组动物的信息。

![Graph showing life spans of animals]

Please give this chart a proper title: 请给这幅图取一个恰当的名字，来表达它的主题：__

What information can you from this chart? 从这幅图中你读出了哪些信息? e.g. Among the five animals in this chart, the rabbit has the shortest life span. 例: 五种动物相比，兔子的生命周期最短。

2. The diagram shows some organisms living together. 左图显示了一些生物共同生活的情景。

![Diagram showing organisms living together]
What is the function and influence of the plants to animals’ lives? Please specify. 在这样一个生活环境中，植物对于动物的生活起到了什么样的影响和作用？请分别说明。

Eg. The tree provides foods for the squirrel. 例：树木为松鼠提供食物

3. The diagram shows a lab dish containing organisms collected at the edge of a forest. 下图是一个实验室的玻璃皿，里面装的是在一个森林边缘捉到的各种小生物。

Please use your own way to categorize them. 你不需要填满所有的空格。

You don’t have to fill up all the cells. 请用一种你自己的方法将上面的小生物分成不同的类别。

<table>
<thead>
<tr>
<th>Letter for Organism 代表生物的字母</th>
<th>Characteristics 特征</th>
</tr>
</thead>
<tbody>
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4. The diagram below represents a species of beetle (ladybug) with two different body colors labeled A and B. These beetles live on trees and are eaten by birds. The percentage of each body color in the population of this species is indicated. The habitat of this beetle population is a group of trees with light-colored bark. Based on the information provided, explain why the beetle population in this habitat contains a higher percentage of beetles with body color A.

下图所示的是一种七星瓢虫。这种七星瓢虫有的颜色较浅，如图 A，有的颜色较深，如图 B。这些瓢虫都生活在一种树皮颜色较浅的树上，鸟儿们以它们为食。据统计，颜色较浅的瓢虫数目占种群总数的 70%，而颜色较深的瓢虫所占的数目为 30%。根据以上信息，请解释为什么在这个区域颜色 A 的瓢虫比例会比颜色 B 的瓢虫比例大得多。
5. The figures below are the ocean food webs for two habitats. As you see in Habitat A you can find cods, but in Habitat B the cods are disappeared because of human being's overfishing. Based on your observation and analysis, which habitat is more dangerous to Elephant seals? Please specify your reasons. 下图是两个海洋区域的食物圈。如图，A区域比B区域多一种生物，那就是鳕鱼。将这两个区域相比，哪一个区域对海象这个物种来说更危险？请说明你的理由。

Figure A (图 A)                                      Figure B (图 B)
6. The diagram below shows a population of adult giraffes over time. Letters A, B, and C represent three time periods. 下图展示的是一个长颈鹿族群中不同类型成年长颈鹿随着时间的变化而出现的变化。A，B，C 分别代表三个不同的时期。

Please state the changes in the adult giraffes population. What are the reasons for this change? 请说出随着时间的推移，长颈鹿族群发生了什么变化？发生这个变化的原因是什么？

7. The diagram shows a food web. 下图展示的是一张食物链网络。

① Please categorize the creatures with your own way, and then state your reasons. 按你的方式给上图中的生物进行分类，并请说明你分类的理由

② If the mice are removed from the food web, which carnivores will be mostly affected, foxes, owls, or
hawks? Explain your reasons. 如果上图中的老鼠消失了，哪种食肉动物受到的影响最大？是狐狸，猫头鹰，还是鹰？请说明你的理由。

③ Please state the relationships among the animals. 请写出上图中动物之间的相互关系。例：猫头鹰与兔子之间是捕食关系。

8. The diagram shows a power station that burns coal (a fossil fuel) to make electricity and the area around it. Please state what impact the power station will bring to the plants and animals in this area. Do you have any suggestions to improve this situation? 下图展示的是一个火力发电厂（燃烧煤等化石燃料用以发电）以及周边的环境。请解释该发电厂对周围的动物和植物会产生什么影响。你对改变这种状况有什么建议吗？
9. Giant panda is one of the China’s special protected endangered species. Its image has become the symbol of Chengdu city and Sichuan Province; World Wild Fund for Nature also uses panda as its trade mark. Currently in China there are 13 preserves and four research center especially for panda protection. The cost for keeping a panda in the research center could be millions of RMB. Do you think it is reasonable? Please state your reasons.

大熊猫是国家一级珍稀保护动物，是成都市和四川省的标志，世界自然基金（World Wild Fund for Nature）的标志也是一只大熊猫。大熊猫受到了国家的重点保护。目前在中国有13个大熊猫的自然保护区，4个大熊猫研究中心。在研究中心里每只大熊猫的花费为每年数百万元人民币。你认为这样做是不是合理？请说明你的理由。

---

**Specification Test Form for Bio-diversity Unit**

<table>
<thead>
<tr>
<th>Test Items</th>
<th>National Standard Correspondence</th>
<th>Expected understanding performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In this column insert the standard content that correspondent to the test items</td>
<td>In these columns check the expected understanding performance of each test item. E.g. recalling, explaining, mustering evidence, finding examples, generalizing, applying concepts, analogizing, representing a concept in a new way, or others (please specify)</td>
</tr>
<tr>
<td>Item 1</td>
<td>Organize and analyze data through using charts and diagrams.</td>
<td>Inferring and analyzing through reading charts</td>
</tr>
<tr>
<td>Item 2</td>
<td>Through studying the knowledge for life science, students seek to understand the variety and interdependency of living species and the basic characteristics of</td>
<td>Inferring and applying knowledge into specific context</td>
</tr>
<tr>
<td>Item</td>
<td>Description</td>
<td>Method</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Item 3</td>
<td>Recognize common animals in the local environment, and be able to categorize them based on certain principles.</td>
<td>Categorizing</td>
</tr>
<tr>
<td>Item 4</td>
<td>Find systematic characteristics or patterns based on the evidences; find the connections among the natural phenomena.</td>
<td>mustering evidence, explaining</td>
</tr>
<tr>
<td>Item 5</td>
<td>Through studying the knowledge for life science, students seek to understand the variety and interdependency of living species and the basic characteristics of living activities.</td>
<td>Analyzing and explaining</td>
</tr>
<tr>
<td>Item 6</td>
<td>Understand the meaning of Darwin’s idea of “the most responsive species survive”.</td>
<td>Inferring, applying concepts, explaining</td>
</tr>
<tr>
<td>Item 7</td>
<td>Through studying the knowledge for life science, students seek to understand the variety and interdependency of living species and the basic characteristics of living activities.</td>
<td>Categorizing Explaining Inferring Applying concepts</td>
</tr>
<tr>
<td>Item 8</td>
<td>Have the sense responsibility to natural resources and environment; care about the sustainable development of the environment; willing to take actions to protect the natural resources.</td>
<td>Inferring Explaining</td>
</tr>
<tr>
<td></td>
<td>Have the sense responsibility to natural resources and environment; care about the sustainable development of the environment; willing to take actions to protect the natural resources.</td>
<td>Explaining</td>
</tr>
</tbody>
</table>
## Appendix F. Coding Scheme for Contribution types of the Online Postings

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Level 2</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q: Questioning</td>
<td>Q1f: Factual question</td>
<td>Questions asking for factual information about “what”(definition), “who”, “when”, &quot;how many/big/long”, etc.</td>
<td>I need to understand: how does the energy transfer from one form to another? (Class B, 09/13/2013)</td>
</tr>
<tr>
<td></td>
<td>Q1e: Explanatory question</td>
<td>Questions asking for reasons, processes, mechanisms and relationships, such as “why does it happen?”, “how does it work”, &quot;what would happen if…?”</td>
<td>Why penguins are birds? Birds should be able to fly, but penguins cannot fly. Why? (Class A, 12/13/2013)</td>
</tr>
<tr>
<td></td>
<td>Q1d: Design question</td>
<td>Questions asking how to design, test, or do something based on knowledge learned</td>
<td>Could you design an experiment to test how the turns of the wire on the coil influence the magnetic force? (Class B, 11/05/2013)</td>
</tr>
<tr>
<td></td>
<td>Q1i: Idea initiating wonderment</td>
<td>A question that searches for general information about a topic. Such questions set the direction of search in a theme-based area, and are typically asked in early phases of inquiry driven by curiosity-based wonderment. The question statements convey limited specific prior knowledge about the topic.</td>
<td>The mighty dinosaurs who had dominated the earth now disappeared, and the tiny cockroaches survived till now. What is deciding the fate of the creatures on the earth? (Class A 11/22/2013)</td>
</tr>
<tr>
<td></td>
<td>Q2d: Idea-deepening/elaborating question</td>
<td>A question that searches for deeper and more specific information (e.g. interpretations, explanations, reasons, connections) on the basis of ideas and</td>
<td>If there are too many species in one system, will it be a lot of fighting among the species? Could that fighting lead to imbalanced eco-system as well? (Class B, 12/10/2013)</td>
</tr>
<tr>
<td>Q1c: idea clarifying questions (Q1c)</td>
<td>A question that asking for the clarification of certain ideas, concepts or statements.</td>
<td>There are many different forms of energy. What is the exact form you are talking about?</td>
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<tr>
<td>T: Theorizing/explaining</td>
<td>T1i: intuitive explanation</td>
<td>(The difference between human beings and animals is: human being can talk, animals cannot. (Class A, 12/05/2013)</td>
<td></td>
</tr>
<tr>
<td>T1a: alternative explanation</td>
<td>A statement that suggests a possible different explanation in disagreement or conflict with existing explanation(s).</td>
<td>You can’t produce energy by moving things around. Energy cannot be produced, or disappear. It can only be transferred from one form to another. (Class B, 09/17/2013)</td>
<td></td>
</tr>
<tr>
<td>T1r: refined/sophisticated explanation</td>
<td>A statement that presents elaborated theory/explanation that involves justification, elaboration, specific processes/mechanisms presented using disciplinary concepts/terms.</td>
<td>I believe that the eggs came out first. I saw a TV show explained this issue. When a new creature is born, it get some genetic mutation. Every time the “ancestor” of the chickens reproduce, their gene changed a little. When an egg got the gene that was closest to the modern chicken, then the chicken came out as genetically modern chicken. This is why eggs came out first. (Class A, 12/05/2013)</td>
<td></td>
</tr>
<tr>
<td>T1c: clarifying explanations</td>
<td>A statement that clarifies a concept, definition or an idea</td>
<td>Although your description is not very clear I guess I got your idea: you are talking about the electromagnets we use for experiment instead of the ones in the real life. (Class A, 10/31/2013)</td>
<td></td>
</tr>
<tr>
<td>T1s: suggestions for next step actions</td>
<td>A statement that provide suggestions for how to take next step actions on clarifying or advancing the ideas</td>
<td>I think you can do an experiment. If the two ends of the nail has different magnetic force, it should attract different amount of paper clips. (Class B, 10/22/2013)</td>
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<tr>
<td>E: Evidence/data</td>
<td>A posting that describes experiments, observations, and other sources of data to either support or challenge an explanation.</td>
<td>(To make the water boiling faster) we can put the cover on the pot. I did an experiment at home. The pot full of water with cover boiled 2 mins faster than the one without cover. (Class A, 10/07/2013)</td>
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<tr>
<td>R: Referencing sources</td>
<td>A posting that introduces information from readings/websites/experts and uses the information to deepen ideas and generate questions.</td>
<td>Coal, oil, natural gas is all biochemical energy. They are the remains of ancient plants and animals buried underground or under the ocean. Burying deep under the ground make it possible for the remains to be kept away from the oxygen. This slows down the oxidation and reduction reaction, and gradually the remains become coal, oil or natural gas. That’s’ how the biochemical energy come into being. (Class A, 12/10/201)</td>
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</table>
| C: Connecting and integrating | A posting that connects different perspectives and topics/areas of work to generate a synthesis, summary, high-order conceptualization, or integrated solution. | Solar energy can be converted into electricity and heat. E.g.: solar battery.  
Electricity can be converted into light. E.g.: lighting bulbs.  
Thermal energy can be converted into electricity. E.g.: thermal power plant.  
In summary, the three forms of energy can be transformed into each other. |
| D: Designing and applying | A posting that describes specific designs or possible applications of the ideas discussed to meet certain need or achieve certain goal. | Experiment design  
Experimental materials: two cells, a big nail, a wire, a compass.  
Procedure:  
1. Put 10 turns of wire on the big nail.  
2. Put the compass next to the nail.  
3. Connect the wire to the cell. |
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<tr>
<td>4. Mark the deflection angle on the compass.</td>
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<td>6. Put 30 turns of wire on the big nail. Repeat step 2 to 4. (Class B, 10/22/2013)</td>
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</table>
### Appendix G. Coding Scheme to Scientificness and Complexity of the Ideas in the Online Postings

<table>
<thead>
<tr>
<th>Categories</th>
<th>Sub-categories and Defining Features</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientificness of ideas</td>
<td>1. Pre-scientific: Misconceptions based on naive conceptual framework (scheme)</td>
<td>(The knowledge I learned in this unit) About energy production: When people move, they produce kinetic energy. About energy transfer: water becomes steam when it evaporates.</td>
</tr>
<tr>
<td></td>
<td>2. Hybrid: Misconceptions that have incorporated scientific information but show mixed misconceptions/scientific frameworks</td>
<td>Bio gas is one type of natural gas, and it can never be used up.</td>
</tr>
<tr>
<td></td>
<td>3. Basically scientific: Ideas based on scientific framework, but not precisely scientific.</td>
<td>What is energy? Energy is the measure of the movement of objects. Corresponding to different forms of movement, there are different forms of energy, such as mechanical energy, molecular energy, electrical energy, chemical energy, nuclear energy and other.</td>
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<td></td>
<td>4. Scientific: Explanations that are consistent with scientific knowledge.</td>
<td>Magnetic energy is a type of energy. We can get energy by eating food. Energy can exist in many forms, such as Kinetic energy, internal energy, potential energy, etc. Energy transform is a process that one form of energy change into another form.</td>
</tr>
<tr>
<td>Epistemic complexity of ideas</td>
<td>Unelaborated facts: Description of terms, phenomena, or experiences without elaboration.</td>
<td>What I have learned in this unit: 1) The concepts of lower consumers, intermediate consumer and senior consumers in the food pyramid. 2) the distribution ratio of different types of animals in the food pyramid. (3) There are many ways to categorize the animals.</td>
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<td></td>
<td>Elaborated facts: Elaboration of terms, phenomena, or experiences.</td>
<td>In the plant kingdom there are over 300,000 different kinds of plants, nearly half of them are flowering plants. Some non-flowering plants, such as ferns, algae, and mosses, manufacture their own nutrients through photosynthesis like the</td>
</tr>
<tr>
<td>Unelaborated explanations: Reasons, relationships, or mechanisms mentioned without elaboration.</td>
<td>What decides the fate of the creatures on the earth? The extinct of dinosaurs is the disaster of the earth. The food chain also decides one animal’s fate. We are the master of the earth, what we do also influence the fate of the animals.</td>
<td></td>
</tr>
<tr>
<td>Elaborated explanations: Reasons, relationships, or mechanisms elaborated.</td>
<td>I think the most appropriate power plants for my hometown should be hydropower plants. My hometown is Chongqing. It does not produce coal, and it usually has little wind. The number of sunny days is small. But it locates right next to Yangtze River close, the flow of the current in this river is very big and fast, so it has great hydro power. So I think hydro power plants should be the most appropriate power source for my hometown.</td>
<td></td>
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</table>
## Appendix H. Major Themes about the Activities and Tool Features that Enables the Assessment Implementation

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Activity</th>
<th>Tool features</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Focus setting: defining the themes to be assessed as valued for the community.</td>
<td>1.1 Students individually create a list of “big ideas” on notebook</td>
<td>1.1 KF views display notes</td>
<td>Ms. Lee: Now I want you to take out your notebook and write down the important ideas in your mind. What ideas we have been discussed a lot? What questions has been very important to us? Think about those ideas and write them down (Video scrip to Class A, 11/20/2013).</td>
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<td>1.2 Community reach consensus about “class idea-list” through class discussion</td>
<td>1.2 Teachers projected the KF view on the screen.</td>
<td>Ms. Lee: OK, now let’s hear your ideas. CLX, what ideas have you got? Student CLX: Energy transforming. Ms. Lee: Energy Transforming? Lets’ see… (pointing at the screen) OK, these ones. And these notes. They are all about energy transforming, right? We had many discussions on this topic. That’s really a good one. Let me write it down (Video script to Class A, 11/20/2013).</td>
</tr>
<tr>
<td>2. Evidence collection: supporting the community to collect accurate and sufficient evidence for their collective knowledge.</td>
<td>2.1 Constructing idea threads with the selected notes</td>
<td>2.1.1 Search notes for the themes</td>
<td>Student LYJ: When our group is creating the threads, we type in the key words and search for the notes. These key words summarize the theme that we explored. This is very helpful. Interviewer: Help you to get the notes from KF? Student: Yes. (Interview to Class B, 01/06/2014)</td>
</tr>
<tr>
<td></td>
<td>2.1.2 Review the notes</td>
<td>2.1 Note searching functions on ITM: supporting students find notes for certain theme</td>
<td>Student ZBX: When we collecting the notes for the theme, we found some notes that we never noticed. For some</td>
</tr>
<tr>
<td>2.1.3 Construct the idea thread with selected notes</td>
<td>Idea thread constructing function on ITM</td>
<td>(Interview with Class A, 11/18/2013)</td>
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<tr>
<td>2.1.4 Edit the idea thread</td>
<td>Removing note function and highlight note function on “idea thread page”</td>
<td>Student LYX: I like the &quot;highlight notes&quot; function. When we see the valuable or high quality notes, we can highlight them, then everybody will be able to notice this note easily. (Interview to Class A, Energy Unit, 11/18/2013)</td>
<td></td>
</tr>
<tr>
<td>2.2 Creating “journey of thinking” for each thread;</td>
<td>2.2.1 Write reflective text “scaffold icons” function on “journey of thinking” page</td>
<td>Student LYJ: (Pointing at “journey of thinking” page) I like these questions. Interviewer: You mean the scaffolds? Student LYJ: Yes. We reflect the knowledge we learned through answering these questions. (Interview to Class B, Biodiversity Unit, 01/06/2014)</td>
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</tr>
</tbody>
</table>
| 2.2.2 Collaboratively refine the text            | 2.2.2 “Historical record” function: allow | Student ZZX: I like this feature. Interviewer: The historical record? Can you tell me your reasons? Student ZZX: This historical
<table>
<thead>
<tr>
<th>2.3 Conducting authentic tasks</th>
<th>Student worked in groups to draw a brief blueprint of a Moon Base on the tablets</th>
<th>2.3 Resources on tablets (drawing tools, graphics library, search engine)</th>
<th>Student HTT: I think designing the Moon Base helps. It is an eco-system, and you have to consider the biological diversity in this system. When you present your design to the class, people asked many questions. These all helped me to understand more knowledge. (Interview to Class B, Biodiversity Unit, 01/06/2014)</th>
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</thead>
<tbody>
<tr>
<td>3. Feedback for reflection: Inferring the achievement and challenges based on the interpretation to the evidence chain.</td>
<td>3.1 Interpreting the representations on idea thread map.</td>
<td>3.1.1 The graphical and statistical representations of idea thread on idea thread map</td>
<td>Student WY: (The map) listed the quantity of the notes in each theme. I also see the names of each theme on this map. I can tell what topics classmates like to discuss, what topics they do not like. (Interview to Class B, Biodiversity Unit, 01/06/2014)</td>
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<tr>
<td>3.1.2. Fan charts on idea thread map</td>
<td>Student YKL: I like the Fan Chart. It shows how each theme distributed. Then we will be able to find out what theme is not deep enough, then we can keep working on it. (Interview to Class B, Biodiversity Unit, 01/06/2014)</td>
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<td>01/06/2014)</td>
<td>3.1.3 Cross-thread connection chart on idea thread map</td>
<td>Student JCR: (Pointing at the Cross-thread Connection Chart) I like this chart. On this chart, I can see theme 6 and theme 1 share nine notes. And some themes, such as theme 3 about &quot;how energy exists&quot; and theme 8 about &quot;the production of energy&quot; share very few notes. This tells me that theme 6 and theme 1 has closer connection. (Interview to Class A, Energy Unit, 11/18/2013)</td>
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<tr>
<td>3.2 Interpreting the evidences from the authentic tasks.</td>
<td>3.2 Projecting the design of the groups on the screen</td>
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<tr>
<td>4. Planning: Use the assessment result to inform the future.</td>
<td>4.1 Group plans for certain threads.</td>
<td>4.1 “We need to do more” text box on “journey of thinking” page</td>
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<td></td>
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<td>&lt;We need do more&gt; We need to understand: Why does an electromagnet has two poles? We need to experiment: Does the winding direction of the wire on the coil influence the magnetic pole of the electromagnet? (Class A “journey of thinking” text for “the mechanism of the electromagnet” thread)</td>
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<tr>
<td>4.2 Class plan for the community’s future collective</td>
<td>4.2 Idea thread map representations</td>
<td>In general: 1. We need to do more experiments and post the results and reflections of the experiments on KF;</td>
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</table>
| inquiry. | 2. People tend to build on the easy questions. We should challenge ourselves with the hard but valuable ideas. About specific themes: 1. The important themes we haven’t discussed yet: the mini motors, 2. The themes that are very valuable but just had few contributions: how to avoid short circuit in the experiment of electromagnet; the sun and the energy. What happens when the battery power up for too long in the experiment of electromagnet? How the energy transferred when a coke can is crushed underfoot? How is energy transformed? How the electricity is generated? How the energy is utilized? 3. The themes that had many contributions but still needs deeper thoughts and different perspectives: The poles of electromagnet, how other energy forms transform into electricity, how electromagnets are used in real life. (Class A’s plan for energy unit 10/24/2013) | 5. Evidence collection, feedback generation and plan making for social dynamics. 5.1 Social network charts on KF | Student WXY: This graph shows people, shows us how much someone interacts with other classmates. It’s like, some students got many arrows pointing to their nodes, and some of them only got one or two arrows. Some even got no connections, looks very lonely. So the other day LYX says she got very few connection lines,
and her node looks very small. So she says she needs to make more connections with others. I think I need to be more active as well. I want to make my node looks bigger. (Interview to Class A, 01/05/2014)

| 5.2 Note distribution on idea thread map page | Student WX: (pointing at the idea thread map on the screen) I found many notes in the beginning, but after the first week, this part, very few notes here. Ms. Lee: What does it mean? Student WX: We were not active in these two weeks. (Video script to Class A, 10/22/2013) |
| 6. Evidence collection, feedback generation and plan making for individual cognition development. | 6.1 Note posting function on KF | Student LYX: I think writing portfolio is helpful. It’s like making a pearl necklace. You connect the pearls together and make a beautiful necklace. Writing reflection is connecting my records and making it looks nice. (Interview to Class A, Energy Unit, 11/18/2013) |
### Appendix I. Main Roles of Teachers in Assessment Process

<table>
<thead>
<tr>
<th>Major Code</th>
<th>Sub-code (level 1)</th>
<th>Sub-code (level 2)</th>
<th>Examples</th>
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</thead>
<tbody>
<tr>
<td>1. Supporting students on adopting their roles as active assessors</td>
<td>1.1 Directly express their expectations to the students as active assessors;</td>
<td></td>
<td>Teacher: I found today the whole class is carefully listening and actively participating into the discussion. This is a big improvement. So many students are contributing to our assessment. You are really working as active assessors for now. I am so proud for you. I had wonderful experience today. Well done. Thank you. (Video script to Class A, 10/22/2013)</td>
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<td>1.2 Inviting and encouraging active participation</td>
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<td>Today I want to show my appreciation to the active contributors. The group who participate the most will get chocolates at the end of class. (Video script to Class A, 11/20/2013)</td>
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<td></td>
<td>1.3 Encouraging students to show appreciations to other people’s contribution</td>
<td></td>
<td>I like WSY’s comments. She found something valuable from this group’s presentation. Appreciating other people’s contribution is critical thinking as well. I hope the rest of you can do that in your comments. (Video script to Class A, 11/15/2013)</td>
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<td>1.4 Encourage the students to take more control on the assessment progress.</td>
<td></td>
<td>Ms. Yong: Why are we creating the idea thread map and interpret it? What’s the purpose of doing these? Student QSY: I think we need to get a better understanding to the questions we had explored. We need to sort them out through using ITM. Ms. Yong: Yes, sorting out questions. Is that the end? Somebody mentioned writing journey of thinking. What did we reflect? Student L YX: We reflected what we</td>
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</table>
did in this unit.
Ms. Yong: What is the purpose of reflecting our achievement in this unit then?
Student ZTL: To find out the problems and we had in this unit, and good learning habits. By doing these we can better overcome our weaknesses.
Ms. Yong: Why should we overcome the weakness?
Student ZTL: For better learning in the next step.
Ms. Yong: Right. We need to get better prepared for next-step learning. What should we do next to get prepared then?
Student WSK: Working hard?
Student ZX: We can make a plan.
Ms. Yong: Make a plan. That’s a good idea. We can make plan for our next-step learning. That’s what we can do today. Make a plan for us. Make a plan to tell us what we should do and how we should do it. (Video transcript to Class A, 10/22/2013)

Supporting students’ conceptual change about working on collective knowledge.

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<tr>
<th>2.1 Directly explain the concepts to the students in certain contexts</th>
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<td>Ms. Lee: What I am trying to say is, after you create the idea threads and wrote journey of thinking, did you find out any problems with your previous discussions? OK, Group 5, could you tell us what problems you found in the threads? Remember, these are not your group’s problems. Your group worked for the whole class. Your group found out the problems for the whole class, so everybody in this class will know what needs to be done with this topic. (Video script to Class B, 12/24/2013)</td>
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| 2.2 Inviting |
| Ms. Lee: Please think about this |
the students to have some discussions for clarifying the purpose of their assessment activities.

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<tr>
<th>3. Supporting students on building criteria for accurate evidence.</th>
<th>3.1 Directly pointed out the problems in students’ work, then invited the students to discuss how the problems should be solved</th>
<th>Ms. Lee: Yesterday I read some “journey of thinking”, and found some are really good on reflecting the progress. I also found some problems. For example, some reflections did not catch the important progress. In the “we need to do more” part, some of the statements got no connections with “we already known”. It’s like the plan comes from nowhere. Let me</th>
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<td>question: Each of your group created one thread for a theme. Did you do this for your group, or for the whole class? Students: For the whole class. Ms. Lee: That's correct. Every group is making a contribution to the whole class' learning. Then I have another question: After I created the threads with my group members, should I only look at the thread that created by my group? Why? Student E, what's your opinion? Student LRZ: We need read other group's threads to improve our own thread. Ms. Lee: Student HJJ, do you have a different idea? Student HJJ: I think we should read other groups’ threads, because we created the idea threads to help the whole class understand the current problems. Ms. Lee: I think HJJ gave us a good reason for read other group’s threads. Yes, every group is creating the thread for the whole class. We should make best use of other group’s effort, shouldn’t we? (Video transcript to Class B, 12/09/2013)</td>
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<td>3.2 Invited the students to reflect on the problems by themselves</td>
<td>show you see some examples. (Class A, 10/22/2013)</td>
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<td>Ms. Lee: Based on the fan chart, what topics are most popular? Student WSK: “How to make an electromagnet” and “other issues”. Ms. Lee: Someone says the “other issues” looks too big. Do you know the reasons? Student WQY: This thread is not carefully screened. Ms. Lee: How do you know that? Student WQY: It got many notes that belong to other threads. This thread is supposed to include the notes that do not belong to any specific topics. Ms. Lee: So this map is not accurate? Students: No. Ms. Lee: What makes an accurate map then? Student HYQ: The threads are screened. Ms. Lee: Yes, big threads need careful screening. We also have some small threads. I found they did not include all the notes that actually belong to them. Student HYQ: Some notes are left out. Ms. Lee: Right. An accurate map is made by accurate threads. We had some threads that have irrelevant notes, we also have some threads that left out the right ones. What can we do with it? Student GYJ: We can refine the threads. Ms. Lee: That’s good suggestions. Let’s do that in your next ICT class. Make sure your thread contains all the notes that belong to this topic.</td>
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<tr>
<td>3.3 Inviting students to rate other group’s or individual’s’ assessment</td>
<td>No irrelevant ones. No left out ones. (Video script to Class A, 10/22/2013)</td>
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<td>Ms. Yong: Who has completed your portfolio writing? Please rise up your hands. OK. If you have completed your work, please first change your title as “completed”. After that, please go to read your classmates’ reflection notes. You need to them a feedback. A score. From 1 to 5. The highest score is 5, and the lowest score is 1. Got it? Students: Can I add decimal? Ms. Yong: Yes, but just one decimal. And you should state at least one reason for your rating in your feedback. (Video script to Class A, 11/13/2013)</td>
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<tr>
<td>4. Supporting the information flow across different social levels.</td>
<td>4.1 Facilitating idea generating and sharing.</td>
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<td>Now we are reaching the end of this unit. Let’s recall our progress together. From the very beginning to present, what big steps did we go through? Who wants to tell us? OK, WQY. (Video script to Class A, 11/15/2013)</td>
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<td>QSY: (In the group presentation) Today, our group will share some results of our discussions to the theme about &quot;energy transfer&quot;. Teacher: I want to clarify, are you presenting the discussions among your group, or are you presenting the achievements of the whole class on this theme? QSY: The achievements of the whole class. (Class A, 11/15/2013)</td>
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<tr>
<td>4.2 Facilitating idea shaping and synthesizing.</td>
<td>4.2.1 Clarify unclear ideas</td>
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<td>You mentioned energy transfer in the water-boiling process. Could you tell us what how the energy is transferred? Is there any energy transformation in this process?</td>
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<td>4.2.2 Redefined ill-defined ideas</td>
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<td>4.2.3 Split too-broad ideas into smaller ones</td>
<td>(Class A, 11/15/2013)</td>
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<td>(Ms. Yong and the students are identifying “big themes” about their discussion on bio-diversity)</td>
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<td>Ms. Yong: What theme do you get, LWT?</td>
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<td>S1: Plants.</td>
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<td>Ms. Yong: Plants? Do you agree with her idea? Those who say no, please state your reasons. YSY, what's your opinion?</td>
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<td>YSY: I think &quot;plant&quot; is too broad. We can build some sub-themes for this one.</td>
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<td>Ms. Yong: What sub-themes?</td>
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<td>YSY: Like the habitat of the plants. And the colors of the plants.</td>
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<tr>
<td>Ms. Yong: You mean the special characteristics of the plants?</td>
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<tr>
<td>YSY: Yes. (Video script to Class A, 11/0/2013)</td>
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<tr>
<th>4.2.4 Rephrase ill-expressed ideas</th>
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<td>(Ms. Lee invited the students to look at two idea thread maps in two different time periods and try to find the differences.)</td>
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<td>HTT: I found some threads got fewer notes on the second map.</td>
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<td>Ms. Lee: Why is that happening? Shouldn't a thread get more contributions along the time?</td>
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<td>ZJ: Some low quality notes are deleted from the threads.</td>
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<td>Ms. Lee: Should we say &quot;deleted&quot; or &quot;removed&quot;?</td>
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<td>ZJ: Removed.</td>
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<tr>
<td>Ms. Lee: Do we have the rights to delete someone's notes?</td>
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<tr>
<td>ZJ: No. (Video script to Class B, 12/09/2013)</td>
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</table>

| 4.2.5 Integrate too-detailed ideas into bigger ones. | Ms. Yong: Let’s look at these ideas on the board. Did you see some ideas can be combined together? |
Some ideas are actually talking about same things?
JYK: the solar panel issue, the power plant issue, and the new energy vehicle issues, are all energy saving issue.
Ms. Yong: You mean they all related to the environment protection?
JYK: Yes.

| 4.2.6 Shared teachers’ own opinions | Ms. Lee: Comments? Nobody got comments for this group? OK, I got a question. You said many notes talked about the experiments in the threads. Those are wonderful ideas. But did you find any experiment reports from the notes?
S1: Yes. This note used a form to report their results.
Ms. Lee: OK, I see. I didn't see that in your presentation. Thank you. (Video script to Class A, 11/15/2013) |
| 4.3 Facilitating consensus reach. | 4.3.1 Accepting appropriate proposals, rejecting the inappropriate proposals, and highlighting the valuable ideas.
(Students were proposing big ideas in their discussion in energy unit.)
Student F: Energy transferring should be a big idea in our discussion.
Ms. Lee: Energy transferring? That’s a really good one. Let me write it down. (Accepting appropriate proposals) (Video script to Class A, 10/22/2013) |
| 4.3.2 Rejecting inappropriate proposals, | (Students were making inquiry plans)
Student Z: We didn’t discuss “the magical electric motor” on page 58.
Ms. Yong: Somebody already mentioned it. It's already in our list. This belongs to the section about “the topics we haven’t discussed”. Now we are talking about the topic we have discussed, but not deep |
| 4.3.3. Highlighting valuable ideas. | (In the “commenting time” after one group’s presentation)  
Student W: The multimedia is an example of energy transferring. It transfer the electricity into light, sound, and heat.  
Ms. Lee: Did you hear what student W just said? He says the multimedia I am using now, is transferring electricity into light, sound, and heat. Isn’t it a wonderful example of energy transferring? (Highlighting the valuable ideas) (Video script to Class A, 11/15/2013) |
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<tr>
<td>4.3.4 Asking for the whole community’s confirmation</td>
<td>Any comments? Are you all happy with this list now? Absolutely no disagreement? (Video script to Class B, 12/09/2013)</td>
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<tr>
<td>4.3.5 Making conclusions about their agreed ideas.</td>
<td>Ms. Yong: OK, today we had many discussions about the idea thread map. Who can stand up and make a conclusion about our discussion results? (Invite the students to make the conclusion about the consensus). (Video script to Class B, 12/12/2013)</td>
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</table>
| 4.4 Facilitating students’ connecting consensus to their individual cognition. | 4.4.1 Write down the students’ consensus on the board  
The teacher wrote down the synthesized ideas on the board. (Class observations, 11/15/2013) |
<p>| 4.4.2 Post students’ consensus on KF | Teacher already posted the plans on KF. (Class observation, 11/17/2013) |
| 4.4.3 Providing scaffold for | The teacher posted a note with the scaffold on the KF and the students |</p>
<table>
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<tr>
<th>4.4.4. Inviting students to discuss how their individual work can connect to the community’s consensus.</th>
<th>Ms. Lee: Those who write their plans based on “Journey of thinking” or idea thread map, please raise your hands. OK. When you look at the threads, what problems did you find? Student YJY: The topic that needs further discussion. Ms. Lee: Which topic? Students YJY: The electric motor. We didn't mention it at all. Ms. Lee: This is part of our class plan, right? Did you write this idea in your plan? Student YJY: Yes. Ms. Lee: Good. Student A writes his plan based on the problems we found. That’s what you are supposed to do in your individual plan. You need to address the issues that we want to solve or forward. I Student B, what is your rationale of writing plan? (Video script to Class A, 10/21/2013)</th>
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<tr>
<td>5. Supporting students on using technology tools in assessment activities.</td>
<td>Ms. Yong: In last class we all made our own idea list. Was it easy to make this list? Students: No. Ms. Yong: Why is that? LXA: Too many notes. ZX: Can’t decide the word for the idea. Ms. Yong: OK, if this is difficult, then what about putting these notes into each idea? Students: Wow… Ms. Yong: Luckily, we got a tool to help us. It is called ITM. Let me show you. (Class B, 11/21/2013)</td>
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<td>the students explore the tool functions.</td>
<td>the tool functions with an example for “the existing forms of energy” together. What should I do first? I need to set up the title, right? OK, which icon should I click? (Class B, 11/21/2013)</td>
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<tr>
<td>5.2.2 Encourage the students to explore the tool functions by themselves.</td>
<td>(Ms. Lee was projecting the idea thread map on the screen) Ms. Lee: Have you tired these icons on the timeline? Who would like to share your experience? LYX: Just now I clicked on &quot;show build on links&quot;, and these lines show up on the map. Ms. Lee: What do these lines mean? Student LYX: I guess, the lines show the build on lines of the notes. One note builds on another on KF. Ms. Lee: Do you agree with her? The ones who agree with her please raise your hands. Yes, LYX is right. It shows the build on connections of the notes. It’s same with KF. Anyone tried other icons? (Video script to Class B, 12/09/2013)</td>
</tr>
<tr>
<td>5.3 Providing emergent technical help.</td>
<td>5.3.1 Teacher provide individual guidance when needed ZZX: Ms. Yong, I can’t change the title of our thread. Ms. Yong: OK, I’m coming (Walk to the student). What’s the problem?</td>
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<tr>
<td>5.3.2 Encourage know-how students to share tips</td>
<td>(After the students tried creating their threads) Ms. Lee: Have anyone experienced any technical problems? WSK: My problem is, some notes from KF cannot be found in the search engine in ITM. Ms. Lee: You mean you cannot find certain notes through using the search engine? Who can help her on this issue? ZHZ? ZHZ: You can type in the whole title into the box, and then search it. You can also copy the title and then paste it in the search box.</td>
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</table>
Ms. Lee: Has someone tried this method? Does it work? OK, Group 7 and Group 8 said it works. Thank you, ZHZ. That's a very useful tip. (Video script to Class A, 10/22/2013)
### Appendix J. Theme List of Two Classes’ Discussions in Two Phases

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<th>Class A</th>
<th>Class B</th>
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<tr>
<td>Energy Unit (Phase 1)</td>
<td>The definition of energy; energy transferring; energy transformation; the existing forms of energy; the applications of electromagnets; the dos and don’ts of the experiments; difference between a magnet and an electromagnet; the magnetic poles of electromagnet; the factors that impact the magnetic power of an electromagnet; the utilization of natural resources; environment protection; energy saving; natural resources saving.</td>
<td>The function of energy; how human body get energy; the production of energy; the storage of energy; energy transferring; the structure of electromagnet; the factors that impact the magnetic power of an electromagnet; the impact of an electromagnet to a compass; energy saving; natural sources saving; the utilization of natural sources; new energy vehicles.</td>
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<tr>
<td>Biodiversity Unit (Phase 2)</td>
<td>The heredity and variation of living creatures; the habits and characteristics of some animals; the habits and characteristics of some plants; eco-system; food chain; the evolution of species; the reproduction of the plants; the reproduction of the animals; the classification of living creatures; rare animals and plants; the relationship between human being and other species.</td>
<td>The extinction of species; the evolution of species; food chain; the habits and characteristics of some animals; the habits and characteristics of some plants; living creatures and environment; rare animals and plants; biodiversity; the relationship among the living creatures; the facial features of human being; the death of the creatures; the classification of living creatures.</td>
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Appendix K. Classroom Observations Protocol

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<th>1. Basic Info</th>
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<tbody>
<tr>
<td>Date:</td>
<td>Classroom:</td>
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<tr>
<td>Teacher:</td>
<td>Data (video/audio/image)Collected:</td>
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<tr>
<th>2. Today’s Focus</th>
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<tr>
<td>Topics and major activities.</td>
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<tr>
<th>3. Detailed knowledge building process/activities</th>
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<td>Describe how the process of knowledge building starts, unfolds and comes to an end.</td>
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<th>4. Ideas &amp; Challenges from students</th>
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<td>List problems or struggles/Ideas or new insights emerging from whole class meeting or small group collaboration.</td>
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<th>5. Teacher’s roles.</th>
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<td>List the important roles that the teacher played in knowledge building process through examples of verbal/non-verbal input from the teacher</td>
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</table>
6. **Discussions with the teachers after class (if applied)**
The comments and ideas that came out from the discussions with the teachers after class, focused on discussing the differences between assessment design and the implementation they had made and they plan to make.

7. **Researcher’s comments**
Highlights the important findings from the observation.