THE EMERGENCE OF ROTATING LEADERSHIP AND COLLECTIVE RESPONSIBILITY IN GRADES 1 AND 4

by

Leanne Ma

A thesis submitted in conformity with the requirements for the degree of Master of Arts
Curriculum, Teaching and Learning
University of Toronto

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ABSTRACT

Building cultural capacity for innovation is an educational imperative. Knowledge Building pedagogy aims to engage students in sustained creative work with ideas from the earliest years of schooling, with all students taking responsibility for creating and advancing community knowledge. In this investigation, the online discourse of grade 1 and 4 students was examined to explore the possibility of identifying rotating leadership, a distinctive feature of cyberteams that create knowledge in out-of-school contexts. Network analyses were conducted to examine leadership patterns at the group level, followed by content analyses to understand leadership behaviours at the individual level. Overall, student networks were relatively decentralized, with many students leading the group at different points in time by connecting new or unique ideas to the class discussion. This research represents the first attempt to integrate Collaborative Innovation Network theory and Knowledge Building. Findings are discussed within the context of education for the Knowledge Age.
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CHAPTER 1  
Introduction

The purpose of this chapter is to establish the context, rationale, and purpose of the current study. First, I introduce the growing need for cultural capacity to innovate. Next, I describe innovative, knowledge-creating contexts and define the central concepts of the current study, rotating leadership and collective cognitive responsibility. The chapter concludes with a statement of the objectives for the current study.

1.1 Study Context and Rationale

In a world of increasing change and complexity, ingenuity of all kinds is needed to generate new concepts, designs, and solutions to address complex social, political, economic, and environmental issues (Homer-Dixon, 2000, 2006; David & Foray, 2003). Given that the health and wealth of nations, as well as the sustainability of the planet, depends on the creation of new knowledge to address increasingly complex problems, building cultural capacity to innovate represents a global imperative (e.g., OECD, 2010, 2015; Ananiadou & Claro, 2009; Keating & Hertzman, 1999). Citizens are finding new ways to actively engage in knowledge creation and bringing about change themselves through virtual networks and communities (e.g., Gloor, 2006; Tapscott & Williams, 2008), but engaging students in knowledge-creating enterprises represents a challenge of a different order. As an educational imperative, schools will need to fundamentally transform their culture in order to prepare students with competencies to innovate and empower them to create knowledge for public good (e.g., Bereiter, 2002; Scardamalia, 2000; Binkley et. al., 2012; Tan & Tan, 2014; Scardamalia & Bereiter, 2014a; Sawyer, 2006; Philip, 2011).

Knowledge Building pedagogy aims to democratize innovation by fostering a culture of creative, sustained work with ideas from the earliest school years, with students taking charge of high-level socio-cognitive functions to advance
community knowledge (Scardamalia & Bereiter, 2003). Parallel to work in
knowledge-creating organizations (Nonaka & Takeuchi, 1995) and Collaborative
Innovation Networks (Gloor, 2006), building community knowledge in the
classroom is social and improvisational. There is no script, members often
surprise one another, and interactions lead to the emergence of creative insights
or solutions (Sawyer, 2003a, 2015). The community may even invoke “creative
chaos” (Nonaka & Takeuchi, 1995), along with other intentional actions to
advance goals, reflecting systematic efforts to solve problems. Each member of
the community knows what needs to be done and self-organizes accordingly
(Gloor, 2006). This phenomenon is known as collective cognitive responsibility
(Scardamalia, 2002, p. 68-69):

“[Whereas] collective responsibility... refers to the condition in
which responsibility for the success of a group effort is distributed
across all the members rather than being concentrated in the
leader. Collective cognitive responsibility involves an added...
cognitive dimension... [Members] also take collective responsibility
for understanding what is happening, for staying cognitively on top
of events as they unfold... [T]hey will also take responsibility for
knowing what needs to be known and for insuring that others know
what needs to be known.”

In knowledge-creating organizations, there is a pervasive culture of learning.
Multilearning (learning across individual, group, and corporate levels) and
multifunctional learning (learning by experience in various domains outside of
one’s expertise) enable employees to take collective responsibility for knowing
the latest advances within and between organizations (Takeuchi & Nonaka,
1986). In Collaborative Innovation Networks, members collaborate openly and
transparently, so that knowledge is made accessible to everyone (Gloor, 2006).
During the creative “swarming” process, several leaders emerge as the group
self-organizes to advance their goals (Gloor, 2006). The emergent phenomenon
of “rotating leadership” implies that the success of the project is achieved by
various leaders – all of whom take collective responsibility for contributing to and
advancing the community goals, such as generating new knowledge, solutions,
products, and other artifacts.
1.2 Study Objectives and Overview

This thesis seeks to contribute to the existing body of literature on knowledge creation in education, with an emphasis on emergent community dynamics. While previous work (e.g., Paavola et. al., 2004; Philip, 2007) has compared Knowledge Building theory with knowledge creation theory, no study has compared Knowledge Building theory with Collaborative Innovation Network theory. Collaborative Innovation Network theory (COIN; Gloor, 2006) represents a relatively new model for understanding community dynamics of knowledge creation, especially in virtual contexts with self-managed cyberteams and online communities. The current study is exploratory in nature, with the central aim of opening a space for dialogue between COIN theory and Knowledge Building theory. By integrating COIN theory with Knowledge Building theory, a new method of analyzing collective cognitive responsibility over time is developed. Rotating leadership is explored in three classroom contexts with young children in grade 1 and 4 (aged 6 to 10 years) engaged in the collective endeavor of creating knowledge of value to the community, while receiving appropriate pedagogical and technological supports. This thesis also aims to inform classroom design-based research, particularly in the areas of pedagogical and technological innovations. Recommendations are offered for future development of automated feedback and assessment tools compatible with virtual Knowledge Building environments, such as Knowledge Forum (Scardamalia & Bereiter, 2014b), that can help boost student capacities for knowledge creation. This thesis is organized into five chapters:

- In Chapter 2, I draw from knowledge creation theory, Collaborative Innovation Network theory, and Knowledge Building theory in order to elaborate on the emergent community dynamics that support the self-organization of members to attain shared goals. I then review studies in Knowledge Building theory as applied to educational contexts and discuss issues surrounding teaching and assessment practices.
• In Chapter 3, I elaborate on the study design, which adapts the COIN concept of rotating leadership into three Knowledge Building classes in order to examine the phenomenon of collective cognitive responsibility for knowledge advancement. More specifically, I explain the measures for social and temporal network analyses, along with the procedures for content analysis to investigate examples of student leadership.

• In Chapter 4, I report findings at the group and individual level for the three Knowledge Building cases: rotating leadership at the group level, followed by descriptions of 5 student leaders for each case. A total of 15 examples of student leadership are presented.

• In Chapter 5, I compare findings across the three Knowledge Building cases and then interpret them in relation to existing knowledge creation literature. I then discuss limitations of this study and situate the implications of the study findings within ongoing conversations about redesigning schools for the Knowledge Age.
CHAPTER 2

Literature Review

The purpose of this chapter is to review recent work related to knowledge creation in organizational literature and educational literature. The literature review is divided into two sections. First, I provide a brief overview of knowledge creation, Collaborative Innovation Networks, and Knowledge Building theory. From each perspective, I describe processes for creating new knowledge and community dynamics that support the emergence of novelty. Then, I highlight and summarize parallels between the three theories. In the second section, I elaborate educational challenges of implementing the Knowledge Building philosophy into teaching and assessment practices. The chapter concludes with a statement of the research questions for the current study.

2.1 Three Models of Knowledge Creation

2.1.1 Knowledge Creation Theory

One of the most influential models of organizational innovation is Nonaka and Takeuchi’s knowledge creation theory (Nonaka & Takeuchi, 1995; see Nonaka, von Krogh, & Voelpel, 2006 for review). In knowledge-creating organizations they have identified “sense of mission” (Takeuchi & Nonaka, 1986) and culture of pervasive, incremental innovation “in which the organization creates and defines problems and then actively develops new knowledge to solve them” (Nonaka, 1994).

2.1.1.1 The Knowledge Spiral

According to Nonaka and Takeuchi (1995), knowledge creation encompasses a dialectical between tacit and explicit knowledge and individual and group functioning. In their dynamic model, knowledge is converted through four
different phases: socialization (from tacit knowledge to tacit knowledge), externalization (from tacit knowledge to explicit knowledge), combination (from explicit knowledge to explicit knowledge), and internalization (from explicit knowledge to tacit knowledge).

![Knowledge Spiral Diagram](image)

**Figure 1. The knowledge spiral (Nonaka & Takeuchi, 1995)**

During socialization, a common, implicit understanding is created in the group through the sharing of emotions and feelings to develop trust and the sharing of mental models to develop a shared goal. During externalization, concepts are generated, reflected upon, and improved. During combination, concepts are evaluated based on the organization’s goals and values before they materialize as a prototype. During internalization, concepts are integrated into the mental models of the group members. The continuous shifting between these four modes of knowledge conversion results in the transformation of existing knowledge into new knowledge; cross-fertilization within the organization and between organizations triggers new cycles of knowledge creation (Nonaka and Takeuchi, 1995). The knowledge spiral (see Figure 1) is used to depict the interactive, cyclical process of knowledge creation.

2.1.1.2 The 5 Conditions for Knowledge Creation

The knowledge spiral is facilitated by five conditions within the organization (Nonaka & Takeuchi, 1995):
CHAPTER 2 | Literature Review

**Intention.** The organization’s goals and aspirations drive the knowledge spiral. They serve as the standard for evaluating the truthfulness and value of knowledge.

**Autonomy.** Individuals act autonomously and self-organize, thereby facilitating unexpected interactions that give rise to new ideas.

**Fluctuation; creative chaos.** Individuals adopt an open attitude toward organizational crises and environment changes in order to improve their habitual routines and practices. Reflection-in-action turns destructive chaos into creative chaos.

**Redundancy.** Intentional sharing of information across different levels of the organization speeds up the knowledge spiral. Redundancy of information can be facilitated through “strategic rotation” of individuals between different departments within the organization.

**Requisite variety.** Diversity within the organization is essential to its adaptation to complex contingencies of the environment.

Nonaka and Takeuchi’s research on multinational companies reveals that the ideal knowledge-creating organization has a flat and flexible structure wherein different departments are interconnected (Nonaka & Takeuchi, 1995). However, in reality, the structure of the knowledge-creating organization must be dynamic as it alternates through phases of structure and flexibility within the knowledge spiral (Nonaka & Takeuchi, 1995). For example, the adaptability and participative nature of activities at the group level supports socialization and externalization, while the specialization and formalized routine of activities at the organizational level supports combination and internalization.

2.1.2 Collaborative Innovation Networks

Collaborative Innovation Networks (COINs; Gloor, 2006; Gloor & Cooper, 2007) represent one of the most powerful drivers of innovation of our time as they set “cool” trends to make the world a better place. Simply defined, a COIN is “a
cyberteam of self-motivated people with a collective vision, enabled by the Web to collaborate in achieving a common goal by sharing ideas, information, and work” (Gloor, 2006, p.4).

2.1.2.1 The COINs Double Helix

According to Gloor (2006), COINs create knowledge in three stages: creation in innovative networks, collaboration in learning networks (CLN), and communication in interest networks (CIN). In the first stage, a core team of self-motivated and enthusiastic individuals is formed through a common shared vision. In the second stage, the creative idea of the core team is taken up by a larger team and leaders are selected by the group throughout various stages of the project. In the final stage, the original product or solution is shared and disseminated to a wider audience.

A double helix is used to depict the evolution of the collaborative innovation processes of COINs, where one spiral represents the community growth and the other spiral represents the knowledge growth (see Figure 2). The evolution of a
COIN to a CIN is recursive and endless as new ideas come out of CINs, and new COINs are formed and, in turn, grow into new CINs.

2.1.2.2 The Principles of Swarm Creativity

COINs share a “collective mindset” based on the following “genetic code” (Gloor, 2006):

- **Autonomy.** Members are self-selected, intellectually curious and highly motivated individuals who are willing to experiment. Their active participation and sustained investment, in turn, strengthens their sense of belonging in the group.

- **Code of ethics.** Members operate based on principles of meritocracy and gain respect based on what they contribute to the group, as well as their altruism toward other members.

- **Knowledge accessibility.** All knowledge is shared openly between members. This act of communal sharing fosters a strong sense of unity in the group.

- **Internal transparency.** Rules, roles, and resources are made explicit to all members. Members support one another’s progress through honest feedback and peer recognition.

- **Mutual trust.** Together, the above shared norms reinforce the shared trust among members, which allows for spontaneous sociability and helps the COIN grow.

Gloor and colleagues’ research on the online communication of international corporations, open-source communities, and grassroots trendsetters reveal that members in COINs have a high degree of connectivity, interactivity, and sharing (Gloor, 2006). More specifically, highly productive and creative teams consist of members who share an innovative language, contribute at similar levels, respond at rapid rates, and maintain a balance between positive and negative
sentiment (Gloor, 2006). Whereas highly productive teams have a stable set of central leaders throughout a project, highly creative teams have many leaders who rotate frequently over time (Gloor, Laubacher, Dynes, & Zhao, 2003; Kidane & Gloor, 2007). Rotating leadership is a distinctive characteristic of COINs, and this phenomenon emerges through self-organization.

2.1.3 Knowledge Building Theory and Pedagogy

Knowledge Building is synonymous with knowledge creation (see Scardamalia & Bereiter, 2006, 2014a; Bereiter & Scardamalia, 2014, for overviews). It involves progressive problem solving through sustained, creative work with ideas, with the ultimate goal of creating knowledge of value to the community (Scardamalia & Bereiter, 2003; Bereiter, 2002). Knowledge Building represents a longstanding effort to redesign education as a knowledge-creating enterprise (Sawyer, 2014; Bereiter & Scardamalia, 2008).

2.1.3.1 Working with Ideas in Design Mode

Knowledge Building does not have a set of stages or phases to depict the knowledge creation process. Instead, a set of principles for knowledge creation serve as design parameters (Scardamalia, 2002; see below). Bereiter & Scardamalia (2003, 2008) distinguish two modes of activity: justification mode in which people are concerned with presenting arguments and evidence in order to arrive at true, justified beliefs, and design mode in which they are concerned with the usefulness, promisingness, explanatory power and improvability of ideas and theories. Though knowledge creation primarily takes place in design mode, flexible movement between design mode and justification mode allows for progressive idea improvement (Bereiter & Scardamalia, 2008). The iterative nature of Knowledge Building is reminiscent of the knowledge spiral of knowledge creation theory and the double helix of COIN theory.

2.1.3.2 The 12 Knowledge Building Principles

Knowledge Building is guided by the following 12 principles (excerpt from Tarchi et. al., 2013):
Real Ideas, Authentic Problems. Students’ ideas and problems of understanding drive knowledge advancement and need to be at the heart of classroom interactions.

Improvable Ideas. From the earliest ages, students understand that ideas are improvable and that working to improve idea quality, coherence, and utility brings their work into line with others trying to create a better world.

Idea Diversity. To create new ideas it is essential to compare and combine diverse ideas, take risks with ideas, and work through complexity rather than focus primarily on asking questions and finding right answers.

Rise Above. Students deal with competing ideas by formulating higher-level ideas that capitalize on the strengths and overcome the weakness of the competing ideas.

Epistemic Agency. Students learn to take over high-level knowledge work (generating ideas and plans, evaluating results, etc.) usually reserved for teachers.

Community Knowledge; Collective Responsibility. Each student accepts responsibility for what the group as a whole is able to achieve, with focus on generating ideas the whole community will find useful.

Democratizing Knowledge. All members of the community find productive roles and take pride in what the group as a whole is able to achieve.

Symmetric Knowledge Advancement. Students recognize that advancing the frontiers of knowledge is a civilization-wide effort in which they can participate, and that contributing to the knowledge advancement of others and of their community returns gains to their own knowledge advancement.

Pervasive Knowledge Building. Students come to see all problems, in and out of school, as occasions for building knowledge.

Constructive Uses of Authoritative Sources. Authoritative sources are
valued means for understanding the state of the art in a field; they are also objects for critical analysis and improvement.

*Knowledge Building Discourse.* The discursive practices of the community engage all participants in transforming ideas, with critical analysis and efforts to go deeper highly valued.

*Concurrent, Embedded, and Transformative Assessment.* Assessment is an integral part of the students’ efforts to advance knowledge, with self- and group- assessment part of the knowledge-building process.

Over the last few decades, Knowledge Building communities have been established in various contexts, such as schools (e.g., Zhang et. al., 2011), universities (e.g., Lax et. al., 2010), health care organizations (e.g., Russell, 2002), school-university-government partnerships (e.g., Laferriere et. al., 2010) and multi-nation research enterprises (e.g., Hong, Scardamalia, & Zhang, 2010). An idea-centered, principle-based design approach emphasizes the role of self-organization in knowledge creation and innovation (Hong & Sullivan, 2009; Scardamalia & Bereiter, 2014b), which is consistent with how existing knowledge-creating organizations and COINs operate.

### 2.1.4 Summary of Three Models of Knowledge Creation

While knowledge creation theory remains to be one of the most influential theories on knowledge creation, various criticisms have been constructed over the years. For example, from an empirical perspective, it has been cautioned that there is insufficient evidence to support the four stages of the SECI model and that rather than “knowledge creation”, the model describes “information creation” (Gourlay, 2006). From a theoretical perspective, there exists a discontinuity between knowledge creation theory and various epistemological perspectives. For example, it has been critiqued that the SECI model does not account for how learning and knowledge acquisition take place (Jorna, 1998; Bereiter, 2002). The clear distinction that is made between tacit and explicit knowledge during each phase of knowledge creation ignores the dynamic
relations between the two types of knowledge, as well as other types of knowledge (Adler, 1995; Gourlay, 2006; Tsoukas, 2003). Additionally, the role of dialogue as an emergent phenomenon in knowledge creation remains an under-explored area (Tsoukas, 2009).

In education, several studies have compared models of innovative knowledge communities – such as knowledge creation theory and Knowledge Building theory – in order to inform the design of collaborative processes of meaning making in the classroom (e.g., Paavola et. al., 2004; Paavola & Hakkarainen, 2005; Philip, 2007). This study adds Collaborative Innovation Network theory as another model for understanding innovative knowledge communities. With regard to the shared community dynamics between these three models, several themes emerge: the collective pursuit of newness; sense of autonomy and volition; open sharing and transparency; progressive discourse, incremental innovation, and innovative language; improvisation and spontaneity in interactions; and collective responsibility and self-organization. Meanwhile, there are important differences required to understand knowledge creation and innovation in different contexts (Bereiter & Scardamalia, 2014). For example, it has been highlighted that whereas in knowledge creation theory, little attention is given to processes aimed at formulating, analyzing, and reflecting on collective problems, in Knowledge Building, systematic problem definition and re-definition is regarded as essential to the process of innovation (Philip, 2007; Engestrom, 1999). A summary of the parallels between knowledge creation, Collaborative Innovation Network, and Knowledge Building theory is provided below in Table 1.
Table 1. Parallels in knowledge creation, Collaborative Innovation Network, and Knowledge Building theory (first column adapted from Tan & Tan, 2014)

<table>
<thead>
<tr>
<th>Group composition and context</th>
<th>Knowledge Creation</th>
<th>Collaborative Innovation Network</th>
<th>Knowledge Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workers in a business organization</td>
<td>Professionals from different domains</td>
<td>Students, professionals, experts, from different domains</td>
<td></td>
</tr>
<tr>
<td>Work context</td>
<td>Virtual context</td>
<td>School, work, virtual contexts</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group goals and vision</th>
<th>Knowledge Creation</th>
<th>Collaborative Innovation Network</th>
<th>Knowledge Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhance the innovativeness and competitiveness of the organization</td>
<td>Collective vision for solving real-life problems by innovating</td>
<td>Collective responsibility for addressing authentic problems</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conditions for knowledge creation</th>
<th>Knowledge Creation</th>
<th>Collaborative Innovation Network</th>
<th>Knowledge Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intentionality, autonomy, fluctuation and creative chaos, redundancy, requisite variety</td>
<td>Intrinsic motivation, ethical integrity, knowledge accessibility, internal transparency, mutual trust</td>
<td>Self organization favourable to 12 Knowledge Building principles (e.g., epistemic agency, collective responsibility)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process of knowledge creation</th>
<th>Knowledge Creation</th>
<th>Collaborative Innovation Network</th>
<th>Knowledge Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dialectic: tacit and explicit knowledge through socialization, externalization, combination, internalization</td>
<td>Central leaders, rotating leadership, honest sentiment, balanced contribution, rapid responses, innovative language</td>
<td>Progressive discourse aimed at working with ideas in design mode; continuous generation and refinement of ideas to achieve higher levels of explanatory coherence and conceptual breakthroughs</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outcome of knowledge creation</th>
<th>Knowledge Creation</th>
<th>Collaborative Innovation Network</th>
<th>Knowledge Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovative products and solutions</td>
<td>Innovative products and solutions</td>
<td>Theories, models, designs, proposals—with some elaborated into innovative products and solutions</td>
<td></td>
</tr>
</tbody>
</table>
2.2 Knowledge Building in Education

Knowledge Building theory applied to educational contexts poses distinctive challenges. In this section, the implications of self-organization and emergence for teaching and assessment practices in a Knowledge Building classroom are discussed.

2.2.1 Teaching Practices

Knowledge Building uses an idea-centered, principle-based design approach to teaching (Hong & Sullivan, 2009). In a typical Knowledge Building classroom, student ideas are at the heart of class discussions. The teacher fosters a sense of community and psychological safety, so that students see their ideas are important and worthy of sharing with others, feel comfortable and willing to take risks with their ideas, and take responsibility for advancing each other’s ideas. The success of the class depends on all members putting the Knowledge Building principles into action.

The Knowledge Building community is formed around shared authentic problems, where members assume collective responsibility for generating diverse ideas and building on one another’s ideas to create community knowledge. Continual idea improvement occurs when members engage in Knowledge Building discourse, making constructive use of authoritative sources, all the while staying in tune with the cutting edge advances of other knowledge communities (symmetric knowledge advancement). Members take on high levels of epistemic agency for setting group goals, democratizing knowledge to ensure equal access to necessary resources, and monitoring group progress via concurrent, embedded, transformative assessment. All ideas are viewed as belonging to the community, subject to scrutiny by its members, tested, retested, improved, synthesized to reach higher levels of understanding (rise above) and to create more powerful theories, designs, and artifacts.

The teacher supports student agency and autonomy by facilitating improvisation in their own practice. One way to achieve this is through
opportunistic collaborative engagement (Zhang, Scardamalia, Reeve, & Messina, 2009; Philip, 2010). Unlike traditional approaches to teaching that rely on a set of instructional procedures, scripted small-group activities, or fixed group arrangements, in opportunistic collaborative engagement, the teacher encourages students to self-organize into groups based on their interests and emergent goals.

For example, in a 3-year study that explored evolving classroom practices of a Knowledge Building teacher, Zhang and colleagues (2009) found that flexible, adaptive social organization and emergent goals led to the greatest advances in community knowledge and individual learning outcomes. In year 1, students directed specific lines of inquiry in fixed groups before coming together at the end to combine their work. The teacher brought up shared problems of understanding to the class, helped with division of labour in small groups, and directed students to sources of information. In year 2, students worked in interacting groups, again specializing in specific topics, but with more opportunities for communication and knowledge sharing between groups. The teacher encouraged groups to collaborate, supported group interaction, and provided more time for students to read each other’s notes and build on each other’s ideas. In year 3, students worked as a whole community in organic groups that formed, disbanded, and reformed small groups based on emergent goals of the community; there were no fixed groups anymore. Students spontaneously and enthusiastically directed the course of the class inquiry, and the teacher provided support by initiating reflective discussions. Social network analyses revealed that the teacher held a central position in Years 1 and 2 when the class was arranged in fixed groups, but was one among many voices in Year 3, when students self-organized into emergent groups (see Figure 3). While the authors found that in all three years, students worked collaboratively around authentic problems and engaged in Knowledge Building discourse to improve ideas in their community, the class in Year 3 made more collective knowledge advances relative to the classes in Years 1 and 2. More specifically, students in Year 3 had the greatest knowledge diffusion between interacting
small groups and greatest gains in scientific content and epistemic complexity of notes, as well as depth of understanding reflected in their individual portfolios (Zhang et. al., 2009). It can be said that the opportunistic-collaboration model supported students in further enacting the principles of epistemic agency, idea diversity, collective responsibility, democratizing knowledge and symmetric knowledge advancement.

Figure 3. Network visualizations of community dynamics, Years 1, 2, 3 (Zhang et. al., 2009)

It is important to note that the collective knowledge advances from this study were experienced by all members of the community, including the teacher. Over the course of the three years, the teacher learned to deepen his trust in student agency, work more comfortably with emergence, and sustain continual idea improvement (Zhang et. al., 2009). The COIN notion that “to get power is to give power” and the Knowledge Building notion that “to give knowledge is to get knowledge” resonate with each other and with Year 3 of the study when the teacher empowered his students by sharing his decision-making process with them and giving his students the freedom to take charge of top-level decisions for the class, such as setting goals, timelines, monitoring advances, and revising goals. In the words of the teacher, “I can begin without having a structure in mind, [and] I can really involve the children in the design of it. In fact, it is the other way around; they involve me in their design” (p. 38, Zhang et. al., 2009).

2.2.2 Assessment Practices

Assessment is key to informing teaching practices (van Aalst, 2013). The principle of embedded, transformative assessment implies that assessment is
integral to the Knowledge Building process. Because the Knowledge Building process is non-linear and non-scripted, assessment must align with the 12 Knowledge Building principles in a way that supports emergence and sustains collective progress (Scardamalia & Bereiter, 2014b). A common way to assess community knowledge at the end of a unit of study is to assess group products, such as student notes and student portfolios and the ideas that helped students get to their current level of understanding (e.g., Lee, Chan, & van Aalst, 2006; van Aalst & Chan, 2007).

Knowledge Building is about change, with emphasis on assessing progress over time, so it is important to focus on idea improvement. Toward that end, researchers have developed principled-based indicators of community knowledge advancement using descriptive statistics and social network analyses to assess interaction patterns within the community, as well as lexical analyses and semantic analyses to assess the course of idea development. Van Aalst and colleagues (2012) developed the Knowledge Connections Analyzer that produces simple visualizations (e.g., bar graphs, pie charts) to display patterns of collaboration in the community based on reading and writing activities online. Their measures included the percentage of notes read, the percentage of notes with build-on links, and the percentage of notes with reference links. Teachers and students found the tool to be intuitive to use and informative for their self-assessment. Philip (2010) used social network diagrams (i.e., sociograms) to visualize communication patterns in the community, such as mutual note-reading, building-on, and co-authoring of notes. Teachers found the tool to be helpful for observing student participation, understanding community formation, and identifying emergent groups within the community. While these quantitative measures are useful for capturing patterns of social interactions and community connectedness, additional qualitative analyses are required to assess the quality of ideas shared between students. Sun and colleagues (2010) developed lexical frequency profiles to assess students’ vocabulary growth. They found that as students worked toward idea improvement and deeper understanding, they used increasingly sophisticated
and specialized vocabulary in their online discourse. Hong and colleagues (2015) used a semantic overlap tool to assess the proportion of shared key terms between students as a means to assess knowledge diffusion for depth and breadth learning. Students reported that the tool was helpful for increasing their collective awareness by giving them a higher-level overview of the community ideas and community goals. In another study, Hong and Scardamalia (2014) found that key term measures were positively related to productive online behaviours, such as writing and editing notes, and working on problems. Similarly, Chen and colleagues (2015) have found that lexical measures were associated with note reading, writing and revising behaviours, with note revising emerging as the strongest predictor of vocabulary growth. Overall, lexical measures seem to complement conventional online behavioural measures by highlighting the key ideas and concepts pursued during the Knowledge Building process (Hong & Scardamalia, 2014; Chen et al., 2015).

In designing Knowledge Building assessments, it is necessary to use a multi-level (individual and group), multi-method (quantitative and qualitative) approach in order to address the interplay of the Knowledge Building principles. For example, Van Aalst (2012) emphasizes the importance of integrating social network analyses with content analyses in order to understand the complex process of collaborative meaning making. As an extension of his argument, this study proposes that the ideal idea-centered, principle-based assessment design would not only include social and semantic aspects, but also temporal aspects of the Knowledge Building process, to better uncover indicators of change. Toward this end, a new method for examining collective cognitive responsibility is introduced.

In this study, social, temporal, and content analyses are used to assess collective cognitive responsibility in three Knowledge Building classes, one of which includes the grade 4 class from Year 3 of Zhang and colleagues’ (2009) study. It is expected that rotating leadership will be an emergent phenomenon of classes where students built knowledge within the opportunistic-collaboration model and self-organized into organic groups based on emergent goals, as in
COINs. It is important to distinguish rotating leadership in COIN theory from forms of strategic rotation found in various organizational frameworks. This study aims to uncover in Knowledge Building is self-organization around idea improvement similar to emergent phenomena in COINs. In contrast, strategic rotation is a structurally-imposed condition used by various problem-solving teams and knowledge-creating organizations (Nonaka & Takeuchi, 1995). In classrooms, a classic, structurally-imposed condition is the jigsaw, which involves predefined teams and rotation of members at specified times (e.g., Aronson, 1978; Brown, 1997; Brown & Campione, 1994; Palinscar & Brown, 1984).

2.3 Current Study

2.3.1 Research Questions

The current study is exploratory in nature, with the aim of integrating COIN theory with Knowledge Building theory in order to develop and apply a new method of analysis for assessing emergent community dynamics. In this study, the possibility of identifying rotating leadership is explored in three Knowledge Building classes. It is hypothesized that if young students are really taking on high levels of collective cognitive responsibility and engaging in knowledge creation via self-organizing processes, rotating leadership would be found as in COINs. The research questions are as follows:

1. At the group level, do young students in a Knowledge Building class show rotating leadership? If they do, how many students assume leadership over the course of their Knowledge Building inquiry?

2. At the individual level, what is happening when a student is leading? What are the different ways that leaders contribute to Knowledge Building discourse?
CHAPTER 3

Methods

The purpose of this chapter is to describe the methodology behind the design of the current study and the methods conducted to answer the research questions of the current study. First, I introduce a mixed methods approach to investigating complex, social phenomena. Then, I outline the methods for data collection method and data analysis for the current study. The analysis phase is divided into two stages: quantitative analyses and qualitative analyses. I describe the procedures in both stages and explain the measures used in the study. I end the chapter by linking the plan of analysis back to the research questions of this study.

3.1 Theoretical Framework

In recognition of the complex, dynamic, iterative nature of the knowledge creation process, a mixed methods design (Greene, Caracelli, & Graham, 1989; Johnson, Onwuegbuzie, & Turner, 2007) was adopted in order to seek elaboration, enhancement, and clarification of results from one method of analysis to the other. More specifically, a sequential approach to data analysis was adopted in order to address the research questions. In the first stage, quantitative methods, such as social and temporal network analyses, were implemented to address the first question. COIN theory (Gloor, 2006) provides an inductive approach for studying group creativity and productivity through a set of objective indicators based on social network theory (Wasserman & Faust, 1994). In the second stage, qualitative methods, such as content analysis of online discourse, were implemented to address the second question. Grounded theory (Glaser & Strauss, 1976) provides a deductive approach to analyzing group interactions and group discourse. By integrating existing quantitative and qualitative methods for studying innovation within organizational and group...
contexts, it is expected that the strength of both types of analysis will be harnessed in order to gain deeper and more holistic understanding of the phenomenon under study: collective cognitive responsibility for knowledge advancement.

3.2 Data Collection

3.2.1 Sampling Method

This study took place at the Dr. Eric Jackman Institute of Child Study of the University of Toronto, where Knowledge Building pedagogy and technology has been used extensively for over a decade. In order to test the hypothesis and validate rotating leadership as a new method of analysis in the Knowledge Building context, a purposive sampling method (Teddlie & Yu, 2007) was used to select three successful Knowledge Building for secondary analysis. The selection criteria included the following characteristics for the classroom samples: 1) students engaged in a sustained inquiry for a minimum of three months, 2) students documented their knowledge advances through extensive writing online, and 3) Knowledge Forum support was integrated into daily classroom practices. Three Knowledge Building classes that met these criteria were selected from the Beyond Best Practice or Ways of Contributing projects during years 2002-2012. Below, they are referred to as Case 1: Grade 4 Light, Case 2: Grade 4 Rocks, and Case 3: Grade 1 Water (see Table 2 for more details).

At the Dr. Eric Jackman Institute of Child Study, classroom activities are designed around the Knowledge Building philosophy, and Knowledge Building technology is an integrated practice in the classroom. Knowledge Forum (Scardamalia, 2004) is a networked, collaboration platform specifically designed to support Knowledge Building community dynamics. Students share and visualize their ideas as notes; create “build-on” notes to connect ideas; and create “rise-above” notes to generate explanations and synthesize ideas. The online community space is synchronized between users in real-time, so that they can easily create, share, and improve their ideas. The environment has
capabilities to support Knowledge Building activities, such as scaffolds for theory building (e.g., ‘I need to understand…’, ‘My theory is…’, ‘A better theory is…’), co-authorship and annotation of notes, and the creation of higher level conceptual spaces to visualize the community knowledge. It also includes a suite of analytic tools to assess student and group performance, such as scaffold usage and vocabulary growth (Chan, 2013). While Knowledge Building discourse can take place in multiple media, Knowledge Forum serves as the central workspace for idea development. Students from these three classes used Knowledge Forum extensively to document and improve one another’s ideas—ideas that were elaborated and refined through observations, experimentation, and constructive use of authoritative sources.

3.2.2 Participants

Case 1 consisted of a grade 4 class with 22 students who engaged in inquiry about light for three months. Students wrote 380 notes across 8 views: Light, How Light Travels, Colors of Light, Light and Materials, Natural and Artificial Light, Shadows, Images in our Eyes and in Films, and All We See Is Light. Student-generated problems of understanding included: rainbows and prisms; transparent, translucent, and opaque objects; convex and concave lenses; mirrors and reflection; and solar and chemical energy.

Case 2 consisted of a grade 4 class with 23 students who engaged in inquiry about rocks for four months. Students wrote 269 notes across 3 views: Rocks and Minerals, Volcano/Lava, and The Big Bang and the Universe. Student-generated problems of understanding included: rocks and minerals; bones and fossil fuels; volcanoes and lava; atoms, matter, and space; the big bang theory; and the theory of evolution.

Case 3 consisted of a grade 1 class with 21 students who engaged in inquiry about water for three months. Students wrote 391 notes across 3 views: All about Clouds, Where did water come from?, and Evaporation. Student-generated problems of understanding included: rain, clouds, and the
atmosphere; oceans, lakes, and rivers; the water cycle; and earth, planets, and space.

Table 2. Summary of Knowledge Building classes and Knowledge Forum data collected for current study

<table>
<thead>
<tr>
<th>Case</th>
<th>Level</th>
<th>Unit</th>
<th>Students</th>
<th>KF Notes</th>
<th>KF Views</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>Grade 4</td>
<td>Light</td>
<td>22</td>
<td>380</td>
<td>8</td>
</tr>
<tr>
<td>Case 2</td>
<td>Grade 4</td>
<td>Rocks</td>
<td>21</td>
<td>269</td>
<td>3</td>
</tr>
<tr>
<td>Case 3</td>
<td>Grade 1</td>
<td>Water</td>
<td>22</td>
<td>391</td>
<td>3</td>
</tr>
</tbody>
</table>

3.3 Data Analysis

3.3.1 Stage 1: Quantitative Methods

Quantitative methods were employed in the first stage of data analysis. An analytic tool called Knowledge Building Discourse Explorer (see below) was used to examine the student discourse in Knowledge Forum. In recognition that Knowledge Building theory emphasizes “idea-centered” rather than “task-centered” activity, traditional social network measures used to examine information exchange between agents (i.e., student-student ties) were adapted to include social-semantic relations between students (i.e., student-word-student ties). In other words, the COIN indicator of rotating leadership was adapted in order to complement the Knowledge Building context. Below, the operational definitions of the quantitative measures used in this study are provided: semantic social networks, temporal networks, betweenness centrality, and rotating leadership.

3.3.1.1 Semantic Social Networks

The student discourse in Knowledge Forum was exported into KBDEx (Knowledge Building Discourse Explorer; Oshima, Oshima, & Matsuzawa, 2012), an analytic tool designed to facilitate content-based social network
analysis for Knowledge Building discourse. Prior to analysis, a list of key words was compiled for each Knowledge Building case in order to facilitate the content portion of the content-based social network analysis of Knowledge Building discourse (see below). Each Knowledge Forum note (which will be referred to as “discourse unit” in this section) was spellchecked to normalize orthographical variations. For each co-authored discourse unit, separate copies for each individual author was made, in order to address the sharing of ideas among co-authors in the social network. Whereas in social network analysis (Wasserman & Faust, 1994; Haythornthwaite, 1996), a typical method used to study information exchange between two agents, networks are created by the agents' social relationships (i.e., shared interactions via send-receive messages), networks for analyses in this study are created by the agents’ semantic-social relationships (i.e., shared ideas via co-occurrence of words in discourse units). For example, in a social network, if A sends a message to B, A and B are connected, as indicated by a line connecting two nodes. If B replies to A, their connection is made even stronger, as indicated by a thicker line connecting two nodes. In a semantic-social network, if C and D use the same word in their discourse units, they are connected, with the strength of their connection increasing as their number of shared words increases. This connection between C and D occurs regardless of whether they engage in a send-receive interaction. This latter method is crucial for analyses of the Knowledge Building discourse used in this study because in Knowledge Forum, students share their ideas to the entire community by posting their note in a two-dimensional public working space; therefore clear interactions between students cannot be traced through traditional social network analysis, particularly send-receive interactions across multiple working spaces.

KBDeX visualizes three network structures using Knowledge Forum discourse as shown in Figure 4: the discourse unit network (bottom left), the words network (bottom right), and the learners network (top right).
These networks are created based on a bipartite graph of words x units. In the discourse network, nodes (i.e., discourse units) will be connected if more than one key word is shared between the discourse units. In the word network, nodes (i.e., words) will be connected if more than one key word is found in a discourse unit. In the learners network, nodes (i.e., students) will be connected if students share more than one key word in their discourse units. The thickness of the edge (i.e., the line connecting two notes) shows the strength of the connection between two students, which is calculated by the number of discourse unit pairs shared for a particular key word. In other words, the learners network represents the extent of idea sharing between students at the word level.

KBDeX allows users to explore the three networks seamlessly in real-time. For example, if the user clicks on a particular student in the learners network, then the discourse units authored by the selected student will be highlighted in the discourse network; as well, the corresponding key words used by the selected student will be highlighted in the word network. This functionality in KBDeX was used during the second stage of analyses (i.e., qualitative
methods) in order to investigate in depth specific stages of the inquiry process and interpret a student’s high betweenness centrality value based on results from the content-based social network analyses.

### 3.3.1.2 Word Lists

For each case, 100 content-related words were extracted from the Ontario Curriculum of Science and Technology for Grades 1 to 8 (Ontario Ministry of Education, 2007) to serve as the benchmark concepts in the community discourse. The main topics of inquiry were not included in these word lists because all students were expected to use these terms regularly in their discussions, which would potentially create overly dense networks and skew analyses of community dynamics.

For Case 1: Grade 4 Light, 100 words were extracted from the “matter and energy” theme and the “earth and space systems” theme (see Appendix A). Examples include: “waves”, “reflection”, “shadows”, “lenses”, and “x-rays”. The main topic of inquiry, “light”, was not included in the word list for Case 1.

For Case 2: Grade 4 Rocks, 100 words were extracted from the “earth and space systems” theme and “matter and energy” theme (see Appendix B). Examples include: “fossils”, “minerals”, “lava”, “meteorites”, and “earthquake”. The main topic of inquiry, “rocks” and “volcanoes” was not included in the word list for Case 2.

For Case 3: Grade 1 Water, 100 words were extracted from the “life systems” theme, “earth and space systems” theme, and “matter and energy” theme (see Appendix C). Examples include: “clouds”, “rivers”, “precipitation”, “evaporation”, and “atmosphere”. The main topic of inquiry, “water”, was not included in the word list for Case 3.
CHAPTER 3 | Methods

3.3.1.3 Temporal Networks

The analysis method used in this study also relies on temporal analysis for social networks. KBDeX has a time control function in which the user can control the time in the discourse. The discourse units are automatically sorted and labelled in chronological order, which allows the user to observe how the networks change over time as the discourse progresses, such as pivotal points in the discourse where a distinctive shape emerges. Additionally, a functionality in KBDeX called the "lifetime" for discourse units was used, which sets the period of time to create the network. The lifetime function creates a temporal network during a more focused period of time, which indicates a short-time trend of the Knowledge Building process. Without the lifetime function, the network structures would indicate the cumulative results of the Knowledge Building process and potentially skew the phenomenon of rotating leadership, with earlier leading students accumulating more influence over time. For this reason, the lifetime function was set to 50 for this study, which is approximately twice the number of students. In the three cases selected, the sample consisted of less than 25 students, so within a lifetime trend of 50, every student would have the chance to contribute at least two discourse units. Furthermore, given the amount of writing that was produced on Knowledge Forum, it was sufficient to capture rotating leadership using a short, focused time trend.

3.3.1.4 Betweenness Centrality

Betweenness centrality measures the extent to which a member influences other members of the group (Gloor et. al., 2003). At the group level, the centralization of betweenness centrality is used to indicate the extent to which the network is centralized. The network is considered centralized when influence is not evenly distributed in the network (i.e., high influence is occupied by a few members of the network). A centralization of betweenness centrality value of 1 means that the network is completely centralized, whereas a value of 0 means that the network is completely decentralized. At the individual level, a betweenness centrality value of 1 means that a member is highly influential,
whereas a value of 0 means that a member is no more influential than other members. When applied to the content-based social network analysis method used in KBDeX, a student would hold an influential position in the note network by sharing key words with other notes. A student would hold an influential position in the word network by using multiple key words in each note. A student would hold an influential position in the learners network by sharing the same key words as other students. Thus, the strength of the betweenness centrality value would rely on synchronicity across the learners, note, and word networks, with key words simultaneously occurring in all three networks.

3.3.1.5 Rotating Leadership Indicator

Recent research in social network analysis shows that group productivity and creativity are indicated by not only a decentralized network structure with a strong leading core, but also rotating leadership, through oscillating patterns of betweenness centrality (e.g., Kidane & Gloor, 2007; Gloor et. al., 2012, Gloor & Paasivara, 2013). During creative group processes, rotating leadership emerges in COINs, as a leading person in the core and a supporting person in the periphery are changing frequently. Group members change influence over time, which implies that the innovation and success of the project is achieved by various contributors leading at various times.

In this study, the COIN method of rotating leadership (i.e., oscillation of individual betweenness centrality) was adopted and integrated into the content-based social network analyses in KBDeX. The leading students were examined directly by using charts depicting changes in betweenness centrality of all students over time (see Figures 5, 16, and 27). KBDeX has a function that allows the user to select each line in isolation and count the number of students taking a leading position manually, as indicated by the highest peaks of betweenness centrality. Whereas a higher ratio of leaders means that the group work was accomplished collectively, a lower ratio means that the group was managed by few strong leaders—perhaps even one leader.
3.3.2 Stage 2: Qualitative Methods

Qualitative methods were employed in the second stage of data analysis. In recognition of the contextual nature of knowledge creation and collaborative meaning making processes (van Aalst, 2012), content analysis (Krippendorff, 2012) was conducted on the Knowledge Building discourse in order to interpret the implications of rotating leadership. Additionally, Tsouka’s (2009) and Sawyer’s (2003b) dialogical approach to knowledge creation emphasizes the importance of examining micro-interactions in dialogue for understanding how ideas grow and spread in a group. Grounded theory (Glaser & Strauss, 1967; Thomas, 2006) was then used to code leadership behaviours in order develop emergent themes for leadership contributions and a preliminary theory for characterizing “leaders” in Knowledge Building.

3.3.2.1 Content Analysis

The class discussions surrounding the top 5 leaders (i.e., students with the highest betweenness centrality) of each case was examined in-depth through content analysis, with a total of 15 leaders examined. More specifically, the notes directly connected to the leader’s notes in the note network, as well as notes (approximately 10 notes) that occurred immediately before and after the leader’s notes were analyzed. By toggling between the three networks in KBDeX, the notes in the note network, the students in the student network, and the ideas in the word network that were connected to a given leader’s were easily identified, which allowed a deeper analysis of how the leader’s contribution influenced the class discussion at a given time. Comparisons of similarities and differences across leader contributions in the three cases allowed for the development of a preliminary framework for interpreting leadership behaviours.

3.3.3 Summary of Plan of Analysis

In adopting the stance that a Knowledge Building classroom is a complex, adaptive system with multiple components interacting at multiple levels, the
research questions in this study are divided according to group and individual levels of analysis. Thus, data analysis was performed in two separate stages in order to address the two research questions. The first stage consisted of quantitative analyses at the group level, where social and temporal network analyses were used to examine group network patterns and determine the number of leaders over time. The second stage consisted of qualitative analyses at the individual level, where the content and context of leading students’ notes were examined in order to identify specific leadership behaviours and situate students’ influence within the progression of the whole-class discussion.
CHAPTER 4

Findings

The purpose of this chapter is to present the findings of the current study. First I report the general findings among the three Knowledge Building cases, then I report the case-specific findings. The case findings are presented from general to specific: rotating leadership at the group level using social and temporal network analyses, followed by detailed descriptions of the top five leaders’ contributions at the individual level using content analysis. For each student leader example, I highlight the key ideas they used in their notes and how their note influenced the contributions of their peers.

4.1 General Findings
First, the average centralization of betweenness centrality was examined for each Knowledge Building case (see Table 3). The average centralization of betweenness centrality values were relatively low for all three classes, which suggests that the student networks were relatively cohesive and decentralized over time – students shared more or less the same level of influence in their networks. Among the three cases, Case 1: Grade 4 Light had the lowest average centralization of betweenness centrality and the highest proportion of leaders in the class, while Case 2: Grade 4 Rocks had the highest average centralization of betweenness centrality and the lowest proportion of leaders in the class. Case 3: Grade 1 Water had the widest range in values for the average centralization of betweenness centrality.
Table 3. Overview of average centralization of betweenness centrality for all three cases

<table>
<thead>
<tr>
<th>Case</th>
<th>Average centralization of betweenness centrality</th>
<th>Proportion of leaders in the class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( m )</td>
<td>( sd )</td>
</tr>
<tr>
<td>Case 1: Grade 4 Light</td>
<td>0.065</td>
<td>0.059</td>
</tr>
<tr>
<td>Case 2: Grade 4 Rocks</td>
<td>0.111</td>
<td>0.050</td>
</tr>
<tr>
<td>Case 3: Grade 1 Water</td>
<td>0.089</td>
<td>0.055</td>
</tr>
</tbody>
</table>

Next, temporal analysis of betweenness centrality (i.e., rotating leadership) was examined in order to identify the top five leaders for each Knowledge Building case. The student networks and the corresponding note networks of the top five leaders were then examined across time. The five leaders for each case are presented in the order of their appearance in order to contextualize their influence within the evolution of ideas in the class discourse.

4.2 Case 1: Grade 4 Light

Figure 5 shows the temporal analysis of betweenness centrality for Case 1. The Y-axis of the chart shows the betweenness centrality value, and the X-axis shows the turn in discussion over time. Each coloured line represents a student, resulting in the display of 22 lines in the chart. The oscillation of coloured, overlapping lines depicts the phenomenon of rotating leadership, which means that the “leader” (i.e., the student with the highest betweenness centrality) changed frequently. Of the 22 students, 17 students were found in a leading position, suggesting that different students were influential at different times. The legend in Figure 5 (top right) indicates the colours of the five students with the highest betweenness centrality values, which means that these students held the most influential positions in the social network. Listed in descending order, they are: student s21 (\( c_b = 0.253 \)), student s18 (\( c_b = 0.248 \)), student s13 (\( c_b = 0.217 \)), student s10 (\( c_b = 0.195 \)), and student s6 (\( c_b = 0.167 \)). While student
s21 had the greatest influence in the student network, student s18 had the longest duration of influence in the student network.

4.2.1 Student s6 at turn 16

The first leader is student s6, who was leading between turns 14 to 16 and peaked at turn 16. The three networks in KBDeX are shown in Figure 6.

The student network in Figure 6a shows that student s6 connected students s7 and s9 to the larger group network, with student s6 having stronger connections.
than student s11. The note network in Figure 6b shows that note 11, written by student s6, linked notes 10 and 13 to the larger cluster of notes. The word network in Figure 6c shows that student s7 connected the concepts of “rainbow”, and “length” to the main discussion of how light travels.

Figure 7 shows in detail how student s6’s notes played an important role in connecting ideas from their peers’ notes in the Colours of Light view. The problem of understanding, as indicated in notes 10 and 14 is how light travels. Among the debate of whether light travels in a wave, zigzag, or straight line, student s7 tried to improve the theory of light travelling as waves, and student s9 tried to improve the theory of light travelling as zigzags. Student s7 proposed that the light waves are so small that they are perceived as straight lines to the human eye. Student s6 added that light waves travel too fast to be perceived by the human eye. Student s6 explained that the colours of the rainbow are arranged based on the lengths of the light waves (i.e., wavelengths) from longest to shortest. Student s7 is the first student to introduce the concepts of “rainbow” and “wavelength” and connect them to the discussion of how light travels, which prompted further discussion surrounding colours of the rainbow (see Students s13, s10, and s18 in this case).
CHAPTER 4 | Findings

4.2.2 Student s13 at Turn 25

The second leader is student s13, who was leading between turns 24 to 30 and peaked at turn 25. The three networks in KBDeX are shown in Figure 8.

![Networks](image)

Figure 8. a) student network, b) note network, and c) word network at turn 25, when student s13 had the highest betweenness centrality

The student network in Figure 8a shows that student s13 connected students s2, s11, and s13 to the larger group network. The note network in Figure 8b shows that note 24, written by student s13, linked notes 25 and 27 to the larger cluster of notes, with note 26 holding a central position in the network (Note: notes 24 and 25 represent a co-authored note). The word network in Figure 8c shows that student s13 connected the concepts of “sun”, rainbow”, “prism”, “bend”, and “eye” to the main discussion of how light travels.
Figure 9. Contents from student s15, s13, s14, and s11’s notes in relation to the note network at turn 25

Figure 9 shows in detail how student s13’s notes played an important role in connecting ideas from their peers’ notes in the How Light Travels view. The problem of understanding, as indicated in note 19 is how light travels. Student s11 applied the theory of light travelling as waves to understand how sunlight reaches the earth, and student s15 added that the size and distance of the sun plays a role in this scenario, which gives rise to the phenomenon of day and night on earth. Students s13 and s14 reported on their experiment using sunlight and a flat prism to make a rainbow. Student s13 synthesized these ideas into a theory of light travelling as crisscrossing waves inside a tube, which makes it appear as a straight line to the human eye. Student s13 is the first student to introduce the concept of light “bending” and connect it to the discussion of how light travels, which prompted further discussion surrounding refraction (i.e., how light bends) (see Students s10 and s21 in this case).
4.2.3 Student s10 at Turn 171

The third leader is student s10, who was leading between turns 151 to 185 and peaked at turn 171. The three networks in KBDeX are shown in Figure 10.

Figure 10. a) student network, b) note network, and c) word network at turn 171, when student s10 had the highest betweenness centrality

The student network in Figure 10a shows that student s10 held a central position in the larger group network. The note network in Figure 10b shows that note 130, written by student s10, was strongly linked to many notes in the larger cluster of notes. The word network in Figure 10c shows that student s10 connected many concepts to the main discussion of how light travels.
Figure 11 shows in detail how student s10's notes played an important role in connecting ideas from their peers' notes in the Lights and Materials view. The general problem of understanding, what is light and how light travels, is summarized in note 130. Student s10 discusses at length ideas surrounding colours, rainbows, and prisms; reflection and absorption; transparent, translucent, and opaque objects; convex and concave lenses; mirrors, angles, and reflection; and natural light as energy.

4.2.4 Student s21 at Turn 175

The fourth leader is student s21, who was leading between turns 166 to 178 and peaked at turn 175. The three networks in KBDeX are shown in Figure 12.
The student network in Figure 12a shows that student s21 connected students s17, s3, and s11 to the larger group network. The note network in Figure 12b shows that note 176, written by student s21, linked notes 139, 157, and 179 to the larger cluster of notes. The word network in Figure 12c shows that student s21 connected the concepts of “focus”, “source”, “magnifying glass”, “sunlight”, “solar energy” and “burn” to the main discussions of lenses and light sources.
Figure 13. Contents from students s21, s11, s3, s17, s6, and s9’s notes in relation to the note network at turn 175

Figure 13 shows in detail how student s21’s notes played an important role in connecting ideas from their peers’ notes in the Natural and Artificial Light view. The problem of understanding, as indicated in note 179 is how sunlight works as an energy source. Student s11 raised a question about how solar energy works, while student s3 shared their theory about how solar panels work, and student s17 described their experiment using sunlight to power light mills. Student s21 synthesized these ideas into a theory about how the source of light would relate to its strength of energy. Student s21 hypothesized that sunlight would be a stronger source than a flashlight and added that a magnify glass could be used to adjust the strength of energy. Student s21’s note connects students s11, s3, and s17’s notes to two larger discussions – one about lenses and magnifying glasses, where student s6 explained how different types of lenses and glasses adjust the strength of light, and the other about natural sources of light, where student s9 discussed the relation between the sun and the stars in space.

4.2.5 Student s18 at Turn 273

The fifth leader is student s18, who was leading between turns 236 to 285 and peaked at turn 273. The three networks in KBDeX are shown in Figure 14.

Figure 14. a) student network, b) note network, and c) word network at turn 273, when student s18 had the highest betweenness centrality
The student network in Figure 14a shows that student s18 held a central position in the larger group network. The note network in Figure 14b shows that notes 255 and 258, written by student s18, was linked to many notes in the larger cluster of notes. The word network in Figure 14c shows that student s18 connected the concepts of “sunlight”, “rainbow”, “flashlight”, “prism”, “shine”, “eye”, “reflect”, and “absorb” to the main discussion of how light travels.

Figure 15. Contents from students s10, s17, s6, and s8’s notes in relation to the note network at turn 273

Figure 15 shows in detail how student s18’s notes played an important role in connecting ideas from their peers’ notes in the Colours of Light view. The problem of understanding, as indicated in note 249 is how light travels through water. Student s5 observed that when light travels through water, its shine and colour are absorbed in the water. Student s18 added that when white light is shined onto an object, some colours are absorbed by the object, and others are reflected into the human eye. Student s18 further hypothesized that the prism will split the white light into the colours of the rainbow. Student s18’s notes connect various ideas from previous discussions, such as “rainbows” and “prisms” (see Student s13 in this case); “reflection” and “absorption” (see Student s10 in this case); and “sunlight” and “flashlights” (see Student s21 in this case), to the larger discussion of how light travels through different media.
4.3 Case 2: Grade 4 Rocks

Figure 16 shows the temporal analysis of betweenness centrality for Case 2. The Y-axis of the chart shows the betweenness centrality value, and the X-axis shows the turn in discussion over time. Each coloured line represents a student, resulting in the display of 21 lines in the chart. The oscillation of coloured, overlapping lines depicts the phenomenon of rotating leadership, which means that the "leader" (i.e., the student with the highest betweenness centrality) changed frequently. Of the 21 students, 10 students were found in a leading position, suggesting that different students were influential at different times. The legend in Figure 16 (top right) indicates the colours of the five students with the highest betweenness centrality values, which means that these students held the most influential positions in the social network. Listed in descending order, they are: student s7 \( (c_b = 0.252) \), student s10 \( (c_b = 0.245) \), student s21 \( (c_b = 0.230) \), student s13 \( (c_b = 0.185) \), and student s17 \( (c_b = 0.174) \). Student s7 had the greatest and longest influence in the student network.
4.3.1 Student s10 at Turn 20

The first leader is student s10, who was leading between turns 16 to 39 and peaked at turn 20. The three networks in KBDeX are shown in Figure 17.

![Figure 17. a) student network, b) note network, and c) word network at turn 20, when student s10 had the highest betweenness centrality](image)

The student network in Figure 17a shows that student s10 connected students s5 and s16 to the larger group network. The note network in Figure 17b shows that note 24, written by student s10, linked notes 16 and 18 to the larger cluster of notes. The word network in Figure 17c shows that student s13 connected the concepts of “stone”, “sand”, and “lava” to the main discussion of rocks and lava.
Figure 18. Contents from students s6, s7, s5, s16, and s10’s notes in relation to the note network at turn 20

Figure 18 shows in detail how student s10’s notes played an important role in connecting ideas from their peers’ notes in the Rocks and Minerals view. The problem of understanding, as indicated in notes 1 and 5 is how rocks and lava are formed. Student s6 wondered how rocks become coloured, while student s7 wondered how lava is created. Student s10 proposed a theory that the composition of the rock (e.g., sand, stone, lava) results in the colour of the rock. Student s16 added that some rocks are composed of hardened sand, and student s15 hypothesized that rocks composed of sand are formed over years under the sea. Student s10 is the first student to introduce the concept of “sand” and connect it to the main discussion of rocks and lava, which prompted further discussion surrounding rock formation and rock composition (see Students s7 and s13 in this case).

4.3.2 Student s7 at Turn 30

The second leader is student s7, who was leading between turns 17 to 47 and peaked at turn 30. The three networks in KBDeX are shown in Figure 10.
Figure 19. a) student network, b) note networks, and c) word networks at turn 30, when student s7 had the highest betweenness centrality

The student network in Figure 19a shows that student s7 connected students s19 and s3 to the larger group network. There are two note networks in Figure 19b: notes 5 and 11, written by student s7, were linked to the larger cluster of notes, while note 6, written by student s7, was linked to the smaller cluster of notes. There are two word networks in Figure 19c: student s7 simultaneously connected the concepts of “diamond” and “compact” in the larger discussion about rocks and lava, and the concepts of “fossils” and “bones” in a smaller discussion about fossil fuels.

Figure 20. Contents from students s8, s14, s6, s7, s19, s3, s14, s13, and s17’s notes in relation to the note network at turn 30

Figure 20 shows in detail how student s7’s notes played an important role in connecting ideas from their peers’ notes in the Rocks and Minerals view (left) and the Volcano and Lava view (right). The first problem of understanding, as
indicated in note 5, is how lava is formed. Student s7 wondered how lava is created. Student s6 theorized that lava may be composed of little hot rocks, and student s14 shared that some types of lava are composed of jagged rocks. The discussion about lava resumes at a later time when student s8 wondered why lava is hot. The second problem of understanding, as indicated in note 6, is how fossil fuels are formed. Specifying that fossil fuels are not the same as bones, student s7 wondered how fossil fuels are created. Student s19 proposed that fossil fuels are composed of crushed fossils, while student s3 elaborates that fossils are composed of bones compressed over long periods of time. The third problem of understanding, as indicated in note 10, is how rocks are formed. Student s17 suggested that rocks are composed of minerals over long periods of time. Student s7 hypothesized that diamonds are also composed of minerals through a process of compaction (i.e., compression). Student s13 proposed a theory that rocks are composed of dried and compacted magma, while student s14 theorized that rocks are composed of compacted dirt and soil, which is where they get their colour. Student s7 is the first student to introduce the concept of “compaction” (i.e., compression) and connect it to the main discussion of rocks and lava, which prompted further theories about rock formation. As well, student s7 is the first to introduce the concept of “bones” and connect it to the discussion of fossil fuels, which prompted further clarification on the relation between fossils and bones.

4.3.3 Student s13 at Turn 65

The third leader is student s13, who was leading between turns 57 to 80 and peaked at turn 65. The three networks in KBDeX are shown in Figure 21.
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Figure 21. a) student network, b) note network, and c) word network at turn 65, when student s13 had the highest betweenness centrality.

The student network in Figure 21a shows that student s13 held a central position in the larger group network. The note network in Figure 21b shows that notes 52, 48, 62, and 65 written by student s13, linked smaller clusters of notes to the larger cluster of notes. The word network in Figure 21c shows that student s13 connected the concepts of “core”, “earth”, “erupt”, “water”, “texture”, and “smooth” to the main discussion of volcanoes and lava.

Figure 22. Contents from students s19, s13, s11, s10, s17, s1, and s7’s notes in relation to the note network at turn 65.

Figure 22 shows in detail how student s13’s notes played an important role in connecting ideas from their peers’ notes in the Volcano/Lava view (top and bottom left) and the Rocks and Minerals view (bottom right). The first problem of understanding, as indicated in note 24 is how the earth was created. Student s11 shared that the big bang created the earth, and student s19 added that the earth is composed of debris from the big bang. Student s13 theorized that the
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Earth’s rotation and the earth’s core affects volcanic eruptions. Student s13 connected student s11 and s19’s ideas to the main discussion of how volcanoes erupt, where student s10 proposed a theory that volcanoes underwater can erupt lava and form new mountains. The second problem of understanding, as indicated in note 28 is how often volcanoes erupt. Student s7 asked if mount St. Helen’s would erupt again. Student s19 hypothesized that the chances of mount St. Helen’s erupting again would be unlikely. Student s13 theorized that a volcano that has erupted recently would not be ready to erupt again, and then improves their theory by adding that volcanoes usually erupt only twice. The third problem of understanding, as indicated in note 37 is how rocks are made. Students s17 and s1 hypothesized that water plays a role in rock formation. Student s13 added that water creates smooth textures in rocks. Student s13 developed multiple theories in order to advance the general discussions surrounding volcanoes and rocks.

4.3.4 Student s17 at Turn 178

The fourth leader is student s17, who was leading between turns 178 to 186 and peaked at turn 178. The three networks in KBDeX are shown in Figure 23.

![Figure 23](image)

Figure 23. a) student network, b) note network, and c) word network at turn 178, when student s17 had the highest betweenness centrality

The student network in Figure 23a shows that student s17 connected students s19, s2 and s20 to the larger group network. The note network in Figure 23b shows that note 145, written by student s17, linked notes 144, 147, and 151 to the larger cluster of notes. The word network in Figure 23c shows that student
s17 connected the concepts of “atoms” and “meteorites” to the main discussion of how the earth was created.

Figure 24 shows in detail how student s17’s notes played an important role in connecting ideas from their peers’ notes in the Rocks and Minerals view. The problem of understanding, as indicated in note 144, is what are atoms. Student s2 asked what atoms are made of. Student s17 hypothesized that the earth is composed of atoms, while student s19 suggested that atoms are made of electrons, a nucleus, and other matter. Student s20 added that atoms move at the speed of light. Student s17 connected students s2, s19 and s20’s ideas to the main discussion of the origin of life in the universe, where student s10 wondered how life started on earth after the big bang.

4.3.5 Student s21 at Turn 262

The fifth leader is student s21, who was leading between turns 247 to 265 and peaked at turn 262. The three networks in KBDeX are shown in Figure 25.
Figure 25. a) student network, b) note network, and c) word network at turn 262, when student s21 had the highest betweenness centrality

The student network in Figure 25a shows that student s21 held a central position in the larger group network. The note network in Figure 25b shows that note 266, written by student s21, was strongly linked to many notes in the larger cluster of notes. The word network in Figure 25c shows that student s21 connected many concepts to the main discussion of the origin and evolution of life on earth.

Figure 26 shows in detail how student s21’s notes played an important role in connecting ideas from their peers’ notes in the Rocks and Minerals view. The problem of understanding, as indicated in note 225 by student s5, is the theory of evolution. Student s21 cites a book on ideas surrounding the life on earth, while summarizing ideas on earth as a planet. Student s21’s notes connect various ideas from previous discussions, such as “sea” (see Student s21 in this case), “bones” (see Student s10 in this case), and “earth” (see Students s13 and s21 in this case) to the broader discussion of rocks, volcanoes, and earth.
4.4 Case 3: Grade 1 Water

Figure 27 shows the temporal analysis of betweenness centrality for Case 3. The Y-axis of the chart shows the betweenness centrality value, and the X-axis shows the turn in discussion over time. Each coloured line represents a student, resulting in the display of 22 lines in the chart. The oscillation of coloured, overlapping lines depicts the phenomenon of rotating leadership, which means that the "leader" (i.e., the student with the highest betweenness centrality) changed frequently. Of the 22 students, 12 students were found in a leading position, suggesting that different students were influential at different times. The legend in Figure 27 (top right) indicates the colours of the five students with the highest betweenness centrality values, which means that these students held the most influential positions in the social network. Listed in descending order, they are: student s17 ($c_b = 0.282$), student s3 ($c_b = 0.217$), student s16 ($c_b = 0.213$), student s7 ($c_b = 0.182$), and student s21 ($c_b = 0.182$). Student s17 had the greatest and longest influence in the student network.

![Figure 27. KBDeX visualization of individual betweenness centralities across time for Case 3: Grade 1 Water](image-url)
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4.4.1 Students s7 and s21 at Turn 15

The first two leaders are student s7 and s21, who were leading simultaneously from turn 12 and peaked at turn 15. Student s7 was leading between turns 12 to 16, while student s21 was leading between turns 12 to 33. The three networks in KBDeX are shown in Figure 28.

![Figure 28](image)

Figure 28. a) student network, b) note networks, and c) word networks at turn 15, when students s7 and s21 had the highest betweenness centrality

The student network in Figure 28a shows that student s7 connected students s17 and s14, while student s21 connected students s11 and s13 to the larger group network. The note networks in Figure 29b shows that note 12, written by student s21, was linked to notes 16 and 11 (note network on left), while note 7, written by student s7, was linked to notes 13 and 6 (note network on right). In the larger cluster of notes, student s21 wrote note 14, and student s7 wrote note 17 (note network in center). The word networks in Figure 28c shows that student s21 connected the concepts of “rain”, and “salt” together (word network on left), while student s21 connected the concepts of “air” and “vapour” together (word network on right). The main discussion was about clouds (word network in center).
Figure 29. Contents from students s21, s13, s11, s7, s17, s14, s15, and s5’s notes in relation to the note networks at turn 15

Figure 29 shows in detail how students s7’s note played an important role in connecting ideas from their peers’ notes in the Evaporation view (right) and how s21’s note played an important role in connecting ideas from their peers’ notes in the Where did water come from? view (left). They also played an important role in the All about clouds view (center). The first problem of understanding, as indicated in note 6 is water vapour. Student s14 proposed that the sun melts water vapour into water. Student s7 suggested that water vapour is air, while student s17 suggested that water vapour is water. The second problem of understanding, as indicated in note 11 by student s11 is how saltwater is made. Student s21 theorized that there salt is found naturally in rainwater, while student s13 theorized that someone added salt to the water. The third problem of understanding, as indicated in notes 14 and 20 is clouds. Student s21 wondered why clouds don’t float into space, while student s5 wondered how clouds stay afloat in earth’s atmosphere. Student s7 proposed that the composition of clouds helps them float, while student s15 theorized that a characteristic of clouds (i.e., they are light) helps them float. While participating in the main discussion about clouds, students s7 introduced the concept of “air”, and student s21 introduced the concept of “rain” to the smaller discussions.
about water, which prompted further discussion surrounding “rain” (see Students s3 and s17 in this case) and “evaporation” (see Students s17 and s16 in this case).

### 4.4.2 Student s3 at Turn 161

The third leader is student s3, who was leading between turns 154 to 169 and peaked at turn 161. The three networks in KBDeX are shown in Figure 30.

![Figure 30](image)

**Figure 30.** a) student network, b) note network, and c) word network at turn 161, when student s3 had the highest betweenness centrality.

The student network in Figure 30a shows that student s3 connected students s8 and s6 to the larger group network. The note network in Figure 30b shows that note 126, written by student s3, linked notes 134 and 125 to the larger cluster of notes. The word network in Figure 30c shows that student s3 connected the concepts of “lake”, “river”, “ocean”, “earth” and “meteorite” to the main discussion of clouds and water.
Figure 31 shows in detail how student s3’s notes played an important role in connecting ideas from their peers’ notes in the Where did water come from? view. The problem of understanding, as indicated in notes 126 and 134 is where water comes from. Student s3 theorized that a meteorite brought water, which created oceans, lakes, and rivers on earth. Student s8 proposed that meteorites brought ice and water, and student s6 elaborated that ice melts into water. Student s10 added their theory that lava from volcanoes turned into water and created the oceans. Student s3 connected students s8, s6, and s10’s ideas to the main discussion of clouds and water, where student s17 wondered why rain falls from clouds.

4.4.3 Student s17 at Turn 218

The fourth leader is student s17, who was leading between turns 211 to 254 and peaked at turn 218. The three networks in KBDeX are shown in Figure 32.
The student network in Figure 32a shows that student s17 connected students s21 and s8 to the larger group network. The note network in Figure 32b shows that note 216, written by student s17, linked notes 193 and 223 the larger cluster of notes, with notes 212 and 196 holding central positions in the network. The word network in Figure 32c shows that student s17 connected the concepts of “earth”, “rain”, “evaporation”, “space”, “sand”, “ice”, and “snow” to the main discussion of clouds and air.

Figure 33. Contents from students s17, s15, s8, s22, s7, and s21’s notes in relation to the note network at turn 218
Figure 33 shows in detail how student s17’s notes played an important role in connecting ideas from their peers’ notes in the Evaporation, All about Water, and Where did water come from? views (from left to right). The first problem of understanding, as indicated in note 177 by student s22, is where water goes to in space. Student s7 theorized that there is snow and ice on planet Mars, while student s21 added that when snow melts, it becomes water. The second problem of understanding, as indicated in notes 186 and 220, is rain and evaporation. Student s15 wondered how rain works, while student 28 wondered how evaporation works. Student s17 theorized that when water evaporates, it becomes a cloud, which will in turn rain down water. In two separate discussions, student s7 connected students s15, s8, s22 and s21’s ideas to the main discussion of clouds and air, where student s3 proposed their theory that the earth’s atmosphere will stop clouds from floating into space and bringing air into space. Student s17 also initiated further discussion surrounding the relation between clouds and the earth (see Student s16 in this case).

4.4.4 Student s16 at Turn 321

The fifth leader is student s16, who was leading between turns 123 to 172 and peaked at turn 321. The three networks in KBDeX are shown in Figure 34.

![Figure 34](image_url)

The student network in Figure 34a shows that student s16 connected student s5 to the larger group network. The note network in Figure 34b shows that note
289, written by student s16, linked notes 316, 283, and 292 to the larger cluster of notes, with note 287 holding a central position in the network. The word network in Figure 34c shows that student s16 connected the concepts of “planet”, “meteor”, “earth”, “ice”, and “hot” to the main discussion of water and evaporation.

Figure 35. Contents from student s6, s16, s12, s18, and s5’s notes in relation to the note network at turn 321

Figure 35 shows in detail how student s16’s notes played an important role in connecting ideas from their peers’ notes in the Evaporation view (left) and the Where did water come from? view (right). The problem of understanding, as indicated in notes 283 is where water comes from. Student s18 suggested the possibility of water coming from another planet. Student s6 asked how water came to other planets, while student s5 theorized that a meteor brought water onto the planet Mars. Student s16 wondered which planet the meteors that brought water and ice to earth came from. Student s16 connected students s18, s6, and s5’s ideas to the main discussion of water and evaporation, where student s16 discussed how hot water evaporates, and student s12 discussed how cold water freezes into ice.
CHAPTER 5
Discussion

The purpose of this chapter is to highlight the main ideas and key findings of the current study. After summarizing and interpreting the three cases of rotating leadership within the context of Knowledge Building theory, I discuss limitations of this study and provide recommendations for future research between COIN theory and Knowledge Building theory. The chapter concludes with a consideration of the implications of the current study within the context of knowledge creation for education in the Knowledge Age.

5.1 Summary of Study

The goal of this study was to explore the phenomenon of collective cognitive responsibility in three Knowledge Building classes. The COIN method of rotating leadership was adapted to examine influential contributions in the student discourse on Knowledge Forum. Results indicate that in all three classes, the student networks were relatively decentralized over time, with many students rotating positions of influence in the networks at various points in time. When students held an influential position, they were at the outer edge or center of the larger student network, connecting other students from the periphery. These students played pivotal roles in the community discourse because they contributed notes that integrated ideas from small-group discussions into the main discussion. Overall, the leading students were introducing new ideas to and/or synthesizing existing ideas in the community discourse. Some leaders developed rise-above theories, while others asked deep questions that sparked new lines of inquiry. The first set of findings in this study, the identification of leadership behaviours, are coherent with an existing framework for understanding the different ways of contributing to Knowledge Building discourse (Chuy et al., 2011). The main categories of Knowledge Building
behaviours include: formulating thought-provoking questions, theorizing, obtaining information, working with information, synthesizing and comparing, and supporting discussion. This framework in turn provides support for rotating leadership by revealing that leaders were engaged in productive Knowledge Building discourse with their peers. Furthermore, it implies that leadership and influence can emerge through various types of contributions in a Knowledge Building community.

Many leaders were also found to be simultaneously engaged in multiple small-group discussions. Moreover, some leaders participated in small-group discussions in separate Knowledge Forum views, suggesting that students became influential after contributing multiple notes in multiple views and participating in sustained Knowledge Building discourse. For this second set of findings, it is interesting to note that while Case 1: Grade 4 Light had the most notes and most views, leaders in this case contributed influential notes in only one view at a time – whereas leaders in Case 2: Grade 4 Rocks and Case 3: Grade 1 Water contributed influential notes in two or three views. It is likely that working with ideas across many spaces (i.e., 8 views compared to 3 views) is more challenging, regardless of the total number of notes in the whole database. (Recall that Case 3: Grade 1 Water produced the most notes.) Similarly, managing 8 views would be more challenging than managing 3 views, which could explain the emergence of more leaders in Case 1: Grade 4 Light. Simply put, when there are more views, more students are needed to take on responsibility for monitoring and managing them, and in turn, it becomes more challenging and complex to integrate ideas across multiple views.

Additionally, it was found that the more keywords a leader used, the greater their influence: One of the most powerful notes was a summary note that contained all of the key concepts and ideas in the community knowledge. This third set of findings is consistent with recent literature in Knowledge Building research, which suggests that a more discursively connected community is conducive to making knowledge advances. For example, knowledge diffusion is facilitated through the creation of a shared vocabulary among students (Hong et.
al., 2015), and community knowledge growth is facilitated by students’ vocabulary growth and vocabulary richness (Sun et. al., 2010).

Findings from this study confirm the hypothesis that rotating leadership can be found in Knowledge Building communities in which participants assume collective responsibility for idea improvement and take a principle-based approach to knowledge creation. The students in these three Knowledge Building communities also exemplify the Knowledge Building principles of epistemic agency, constructive use of authoritative sources, idea diversity, democratizing knowledge, symmetric knowledge advancement, real ideas, authentic problems, and rise-above. Students took on high levels of epistemic agency by introducing new ideas from authoritative sources, connecting diverse ideas together, all the while democratizing knowledge by facilitating the flow of ideas from small groups into the context of the large group discussion. They supported symmetric knowledge advancement of the small groups, which prompted further syntheses and elaboration of authentic ideas/problems into rise-above theories and explanations. From a COIN perspective, students operated based on an implicit code of ethics, where every student’s contribution was respected and valued. There was mutual trust and internal transparency so that honest feedback was provided through peers as a means to support and grow one another’s ideas. The knowledge creation environment, Knowledge Forum, allowed for ideas and knowledge to be made accessible for everyone in the community, however, it was emergent, rotating leaders that furthered the interconnectedness between these ideas, and ultimately, the growth of the community knowledge.

5.1.1 Limitations

As this is the first case of applying rotating leadership to a Knowledge Building context, the findings are exploratory and descriptive in nature, opening the possibility of future work at the intersection of COIN theory and Knowledge Building theory, all the while raising several issues that need to be addressed.
The first set of issues surrounds the method used in this study. It should be noted that Gloor’s (2006) original method of social network analysis was adapted to the Knowledge Building context. Social, semantic, and temporal analyses were integrated into content-based social and temporal network analyses in order to develop a more idea-centered approach for assessing Knowledge Building. Thus, student networks were formed based on shared use of key concepts in the community discourse rather than the exchange of information online. Comparisons between the traditional social network analysis method and the new content-based social network analysis method, both applied to additional Knowledge Building contexts, will help determine the appropriateness of such temporal visualizations of collective cognitive responsibility in Knowledge Building. Moreover, because there was no intervention group in this study, it cannot be concluded that rotating leadership in Knowledge Building leads to greater productivity and creativity as it does in COINs. Future work will be needed to assess the outcome of rotating leadership, as well, to develop measures of productivity and creativity within the Knowledge Building context.

Regarding the analytic tool used, several iterations of data cleaning were involved in order to prepare the data for analyses. Due to KBDeX’s sensitivity to specific word input, orthographic variations and synonyms are not automatically accounted for. Student notes were spellchecked manually and word lists were verified manually for domain specificity prior to using KBDeX, then notes were assessed outside of KBDeX for quality analysis, resulting in a labour-intensive process. It would be helpful if future developmental work on KBDeX automated aspects of the data preparation process such as: spellchecking the student notes as Knowledge Forum data is exported, providing a family word list from which users can select, adding a key word dictionary/thesaurus component, or incorporating an annotation feature on top of the network visualizations. It should also be noted that KBDeX’s sensitivity to the user-generated word list opens the opportunity for further validation of the content-based social network analysis. For example, the lists created in this study were specific to the Grade 1
to 8 Science Curriculum in Ontario, Canada – it is striking that young students in Grade 1 and 4 discussed topics beyond their grade level. At the same time, their discussion touched upon ideas that were beyond the Science Curriculum, which were not examined in the word lists entered in KBDex for this study. Thus, comparisons of content-based social network analyses with variations of content-based word lists may affect the emergence of rotating leadership and perhaps yield a different number of leaders. Possible variations of word lists include incorporating more advanced words that correspond with expert vocabulary used in real-world Knowledge Building communities, which can be retrieved from textbooks, encyclopedias, scientific journals, and other authoritative sources.

Regarding the analytic methods employed for assessing the social-semantic interactions, only specific student behaviours could be identified, not students’ intentions nor perceptions. Future work could enable a more multi-dimensional approach to analysis by incorporating multiple sources of data, such as classroom video recordings, student questionnaires, and teacher interviews, in order to validate findings. For example, it would be interesting to compare the Knowledge Building discourse and group interactions that took place online with those that took place in face-to-face discussions within the same Knowledge Building community. It would also be interesting to replicate this study across other Knowledge Building communities in different social, linguistic, and cultural contexts.

The second set of issues surrounds the sample of this study and the generalizability of the results. From the perspective of Kurt Fischer’s theory of cognitive development (Fischer, 1980; Fischer & Pipp, 1984), the current conditions for studying rotating leadership were “optimal” as they represented performance observed under highly supportive conditions. In contrast, “functional” performance can vary over a range of ages and contexts. Thus, the current study taps potential rather than typical performance as the teachers were committed to implementing and improving their Knowledge Building practice as the basis for the collaborative research projects. Moreover, the
school is committed to the Knowledge Building philosophy; for that reason, most of the students in this study were socialized in a school culture that emphasized student agency and autonomy and where the average level of literacy was fairly high. In the intervening years, much has been learned that might improve on these results; nonetheless, reported results may not be readily attainable in other contexts. At the same time, research is underway to identify contexts within this school that do not lead to rotating leadership. The phenomenon is clearly context sensitive, and it is essential to study more diverse student populations and classroom contexts.

5.1.2 Future Directions

While previous work has compared knowledge creation theory with Knowledge Building theory, no study has compared COIN theory with Knowledge Building theory. This study demonstrates that rotating leadership appears to be an emergent phenomenon of a Knowledge Building class. Coherent findings from two different fields – organizational management and education – support theoretical assumptions of each: for Knowledge Building that its theory, pedagogy, and technology do indeed reflect knowledge creation dynamics and for COIN theory that rotating leadership taps a generalizable phenomenon of innovative teams. In joining these two theories together, a new space of exploration on innovative knowledge communities has emerged.

Future research in Knowledge Building theory should explore the practical implications of rotating leadership in Knowledge Building classrooms. More work is needed in order to understand the Knowledge Building teaching and assessment practices that give rise to the phenomenon of rotating leadership. Which classroom configurations support emergence, self-organization, and rotating leadership? How can rotating leadership be sustained in order to support continual idea improvement and pervasive Knowledge Building in the classroom? How can rotating leadership be used for group- and individual-level assessment?
As a new method for assessing collective cognitive responsibility, rotating leadership has the potential to serve as an analytic tool for Knowledge Building classrooms in order to provide formative feedback to both teachers and students alike. In designing Knowledge Building assessments, it is important to integrate social network analysis with content analysis (van Aalst, 2012). Thus, the social, semantic, and temporal visualization represents only the first part of assessment; quality analysis of student notes must be conducted afterward. Previous work using KBDeX as a formative feedback tool examined the student network for community cohesiveness (Matsuzawa, Tohyama, & Sakai, 2014) and the word network for idea improvement (Matsuzawa et. al., 2012). It would be interesting to see how these three lines of research on Knowledge Building assessment, all using KBDeX, complement one another. That being said, this assessment method should be used with discretion. It is not recommended to use rotating leadership as a prescriptive benchmark for standardizing the group process – the goal is not to compare and compete for leadership – instead, it would be more beneficial to use rotating leadership as a descriptive indicator of group creativity and group progress and to find ways of monitoring the phenomenon as work proceeds. Under such conditions, perhaps the students who did not assume a leadership role would have found the opportunity to do so.

Future research in COIN theory should examine the theoretical implications of discovering Collaborative Innovation Networks inside Knowledge Building communities. For example, how do these Collaborative Innovation Networks form and how do they evolve into Collaborative Knowledge Networks? In the current study, many leaders were found in each Knowledge Building case, which supports the notion that successful COINs have a strong core (Gloor, 2006). Further content analysis is needed in order to understand the role and contributions of secondary and tertiary leaders given such scenarios.

Rotating leadership and central leaders represent two of the six honest signals from COIN theory (Gloor, 2006). Another promising line of research would be to integrate the other honest signals, such as response rate,
contribution rate, balanced sentiment, and innovative language, with existing Knowledge Building measures, such as lexical richness and semantic overlap (e.g., Chen et. al., 2015; Hong et. al., 2015). For example, innovative language may be a marker of students working with ideas in design mode and may be associated with the growth of specialized vocabulary; informal research in Knowledge Building indicates that the principle of \textit{idea diversity} is reflected in entry of unique terms, assessed through a vocabulary-growth measure available in Knowledge Forum analytic tools.

While the findings from this study are coherent with Knowledge Building theory and COIN theory, they also complement other literature in knowledge creation. When students were working with ideas in design mode and connecting diverse ideas together, two types of discursive moves emerged: convergent moves that sought explanatory coherence for theory development and divergent moves that sought new problems of understanding. This interplay between convergence and divergence of ideas support the iterative nature of knowledge creation (Nonaka & Takeuchi, 1995) and the upward trajectory of continual idea improvement (Bereiter & Scardamalia, 2008). In addition, this depiction of working with “design mode” in Knowledge Building communities is reminiscent of the group dynamics in innovative design firms and knowledge-creating organizations, which follow a double-diamond model based on multiple iterations of convergence and divergence (Norman, 2013; Brown, 2007; Nelson & Stoltzerman, 2003).

Perhaps one of the most interesting findings in this study is the role of Knowledge Forum for supporting convergent and divergent processes in Knowledge Building. While leaders in Knowledge Building communities are often working in multiple spaces in an attempt to introduce and develop new ideas, having too many working spaces may become an obstacle to bringing diverse ideas together. Thus, new technological designs are needed to support the visualization of ideas across multiple idea landscapes from multiple perspectives in order to enable knowledge advances (Scardamalia & Bereiter, 2015; 2014b). Moreover, such designs may have the potential to facilitate
rotating leadership and enable all members of the Knowledge Building community to take on higher levels of collective cognitive responsibility.

5.2 Implications of Study

Unlike traditional classrooms that operate in a hierarchical system of control, Knowledge Building classrooms operate in a COIN fashion – dynamic, decentralized networks, where control is continuously shifted between members. It is striking that in certain classroom contexts, when teachers share their decision-making power with their students, students as young as 6 years of age are capable of collaborating in self-organized teams in order to achieve their collective goal of advancing knowledge. For example, opportunistic collaboration and the continuous reorganization of groups contribute to the success of Knowledge Building communities with 9 and 10 year-old students (Zhang et. al., 2009). This study adds that rotating leadership is an emergent phenomenon in successful Knowledge Building communities, regardless of the age of students. It is likely that rotating leadership facilitates the distribution and spread of expertise in the community so that students can improve ideas and advance the state of their collective knowledge.

In the Knowledge Building classroom, all students are viewed as essential members of the community and legitimate contributors to the community knowledge; thus, all students should be viewed as capable leaders of the Knowledge Building process. Knowledge Building pedagogy represents one way to move education from the margins to the center of innovation networks and the Knowledge Society. In Drucker’s vision of the Knowledge Society, “for the first time in history, the possibility of leadership will be open to all” (1994, p. 67). The COIN concept of rotating leadership represents one way to depict this sharing of leadership and collective responsibility for knowledge creation and innovation. Knowledge Building pedagogy has the potential to democratize knowledge—to go beyond engaging students collaboratively to empowering them to take charge at the highest levels of agency for creating knowledge for their community. While not every child will grow up to be a
knowledge worker, schools can provide a supporting role in helping students develop their capacity to collaborate, communicate, and innovate so that they may find a place for themselves in varied contexts in a Knowledge Society (Scardamalia, Bransford, Kozma, & Quellmalz, 2012).


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REFERENCES


REFERENCES


REFERENCES


REFERENCES


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APPENDIX A

Word List for Case 1: Grade 4 Light

absorb  heat  reflect
adaptation  illumination  refract
additive  image  revolution
angle  incandescent  rotation
artificial  infrared rays  season
beam  intensity  secondary
bend  invisible  shine
binoculars  kaleidoscope  shadow
bright  length  shape
bulb  lens  solar
burn  luminous  source
camera  lunar  spectroscopes
chemical  magnify  spectrum
concave  medium  speed
contact  microscope  stars
convex  microwave  straight
dark  mirror  subtractive
day  mix  sun
eclipse  moon  sunlight
electrons  natural  surface
electricity  neon  telescope
electromagnetic  night  temperature
etmit  opaque  transfer
effect  optics  translucent
energy  panel  transmit
eye  particle  transparent
fire  path  travel
fireflies  periscopes  ultraviolet
flashlight  primary  visible
fluorescent  prism  wave
focus  radiation  wavelength
glow  radio  x-rays
glare  spectrum
head  superposition
illumination  surface
image  telescope
incandescent  temperature
infrared rays  transfer
tint  translucent
intensity  transmit
invisible  transparent
kaleidoscope  travel
length  ultraviolet
lens  visible
luminous  wave
mix  wavelength
mirror  x-rays
magnify  y-rays
## APPENDIX B

### Word List for Case 2: Grade 4 Rocks

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<thead>
<tr>
<th>Air</th>
<th>Erosion</th>
<th>Meteorite</th>
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<td>Aluminum</td>
<td>Erupt</td>
<td>Mineral</td>
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<td>Atmosphere</td>
<td>Evolve</td>
<td>Molecules</td>
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<td>Atoms</td>
<td>Explode</td>
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<td>Bones</td>
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<td>Burn</td>
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<td>Calcium</td>
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<td>Carbon</td>
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## APPENDIX C

Word List for Case 3: Grade 1 Water

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