Rotating leadership and collective responsibility in a grade 4 Knowledge Building classroom

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Abstract: Productive collaborative engagement in increasingly global, innovative enterprises requires feeling at home with complexity and knowledge creation. Knowledge Building aims to engage students directly in sustained creative work with ideas from the earliest years of schooling, with all students taking responsibility for advancing community knowledge. Knowledge Forum technology aims to make knowledge-creating interactions integral to day-to-day knowledge work and extensible to all students, creating opportunities for rotating leadership, a feature of collaborative innovation networks. In this study we examined social network patterns of rotating leadership in an elementary school class and the discourse moves associated with temporary leadership. We found a relatively decentralised student network, with 20 out of 22 students leading the group at different points in time by connecting unique ideas to the larger class discussion. Our findings are discussed within the context of education for the Knowledge Age.

Keywords: Knowledge Building; collaborative innovation network; collective responsibility; rotating leadership; self-organisation; opportunistic collaboration; knowledge creation; innovation.

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1 Introduction

The health and wealth of organisations and nations depends on new knowledge to address increasingly complex problems; in turn, the well-being of citizens depends on feeling at home in knowledge-creating enterprises (Homer-Dixon, 2000, 2006; OECD, 2010, 2015; David and Foray, 2003; Keating and Hertzman, 1999; Scardamalia and Bereiter, 1999). Knowledge Building aims to democratise 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 and Bereiter, 2003). Parallel to work in knowledge-creating organisations (Nonaka and Takeuchi, 1995) and collaborative innovation networks (Gloor, 2006), building community knowledge in the classroom is improvisational. Members often surprise one another with interactions leading to the emergence of creative insights or solutions (Sawyer, 2003a, 2015). The community may even invoke 'creative chaos' (Nonaka and Takeuchi, 1995), along with other intentional actions to advance goals, reflecting systematic efforts to solve problems. Community members intuitively know what needs to be done and self-organises accordingly (Gloor, 2006). This phenomenon is known as collective *cognitive* responsibility [Scardamalia, (2002), pp.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 organisations 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 organisations (Takeuchi and 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-organises 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 the community knowledge and community artefacts.

The purpose of this paper is to examine the phenomenon of collective cognitive responsibility in a grade 4 Knowledge Building class. We draw from models of Knowledge Building/knowledge creation and collaborative innovation networks (COINs) to explore dynamics for self-organisation surrounding emergent, shared goals. Social and temporal network analyses employing the COIN method of rotating leadership were used to assess collective cognitive responsibility, along with content analysis to examine cases of student leadership. We situate our findings within ongoing conversations about redesigning schools for the Knowledge Age (e.g., Bereiter, 2002; Scardamalia, 2000; Sawyer, 2006; Philip, 2011).

2 Literature review

In this section, we discuss models for conceptualising knowledge creation, collaborative innovation networks, and Knowledge Building. From each perspective we elaborate community dynamics that support the emergence of new knowledge, we then discuss parallels between the models.

2.1 Knowledge creation

One of the most influential models of organisational knowledge creation was developed by Nonaka and Takeuchi (1995; also see Nonaka et al., 2006 for review). Knowledge creating organisations are characterised by 'sense of mission' (Takeuchi and 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). We elaborate their model here in line with the goal of understanding school-based Knowledge Building communities as knowledge-creating organisations.

2.1.1 The knowledge spiral

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

During socialisation, 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 externalisation, concepts are generated, reflected upon, and improved. During combination, concepts are evaluated based on the organisation's goals and values before they materialise as a prototype. During internalisation, 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-fertilisation within the organisation and between organisations triggers new cycles of knowledge creation (Nonaka and Takeuchi, 1995). The knowledge spiral is used to depict the interactive, cyclical process of knowledge creation.

2.1.2 The five conditions for knowledge creation

The knowledge spiral is facilitated by five conditions within the organisation (Nonaka and Takeuchi, 1995):

1. *Intention*. The organisation's goals and aspirations drive the knowledge spiral. They serve as the standard for evaluating the truthfulness and value of knowledge.
2. *Autonomy*. Individuals act autonomously and self-organise, thereby facilitating unexpected interactions that give rise to new ideas.
3. *Fluctuation; creative chaos*. Individuals adopt an open attitude toward organisational crises and environment changes in order to improve their habitual routines and practices. Reflection-in-action turns destructive chaos into creative chaos.
4. *Redundancy*. Intentional sharing of information across different levels of the organisation speeds up the knowledge spiral. Redundancy of information can be facilitated through 'strategic rotation' of individuals between different departments within the organisation.
5. *Requisite variety*. Diversity within the organisation 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 organisation has a flat and flexible structure wherein different departments are interconnected (Nonaka and Takeuchi, 1995). However, in reality, the structure of the knowledge-creating organisation must be dynamic as it alternates through phases of structure and flexibility within the knowledge spiral (Nonaka and Takeuchi, 1995). For example, the adaptability and participative nature of activities at the group level supports socialisation and externalisation, while the specialisation and formalised routine of activities at the organisational level supports combination and internalisation.

2.2 Collaborative innovation networks

Collaborative innovation networks (COINs; Gloor, 2006; Gloor and 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].

2.2.1 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. 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.

2.2.2 The principles of swarm creativity

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

1 *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.

2 *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.

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

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

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

Gloor et al.’s 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 et al., 2003; Kidane and Gloor, 2007). Rotating leadership is a distinctive characteristic of COINs, and this phenomenon emerges through self-organisation.

2.3 Knowledge Building

Knowledge Building is synonymous with knowledge creation (see Scardamalia and Bereiter, 2006, 2014a; Bereiter and 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 and Bereiter, 2003; Bereiter, 2002). Knowledge Building represents a longstanding effort to redesign education as a knowledge-creating enterprise (Sawyer, 2014; Bereiter and Scardamalia, 2008).

2.3.1 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 and 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 and Scardamalia, 2008). The iterative nature of Knowledge Building is reminiscent of the knowledge spiral of knowledge-creating organisations and the double helix of collaborative innovation networks.

2.3.2 The 12 Knowledge Building principles

Knowledge Building is guided by the following 12 principles (excerpt from Tarchi et. al., 2013):

1 *Real ideas, authentic problems*. Students' ideas and problems of understanding drive knowledge advancement and need to be at the heart of classroom interactions.

2 *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.

3 *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.

4 *Rise above*. Students deal with competing ideas by formulating higher-level ideas that capitalise on the strengths and overcome the weakness of the competing ideas.

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

6 *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.

7 *Democratising knowledge*. All members of the community find productive roles and take pride in what the group as a whole is able to achieve.

8 *Symmetric knowledge advancement*. Students recognise that advancing the frontiers of knowledge is a civilisation-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.

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

10 *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.

11 *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.

12 *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), healthcare organisations (e.g., Russell, 2002), school-university-government partnerships (e.g., Laferrière et al., 2010) and multi-nation research enterprises (e.g., Hong et al., 2010). An idea-centred, principle-based design approach emphasises the role of self-organisation in knowledge creation and innovation (Hong and Sullivan, 2009; Scardamalia and Bereiter, 2014b), which is consistent with how existing knowledge-creating organisations and COINs operate.

2.4 Summary of three models of knowledge creation

In studying models of innovative knowledge communities, Paavola et al. (2004) have compared Knowledge Building and knowledge creation. We add collaborative innovation networks 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; innovative language, progressive discourse, and incremental innovation; improvisation and spontaneity in interactions; and collective responsibility and self-organisation.

Meanwhile, there are important differences required to understand knowledge creation and innovation in different contexts (Bereiter and Scardamalia, 2014). Below, we provide a summary of our discussion in Table 1.

Table 1 Parallels in knowledge creation, collaborative innovation networks, and Knowledge Building

	Knowledge creation	*Collaborative innovation network*	*Knowledge Building*
Group composition and context	Workers in a business organisation	Professionals from different domains	Students, professionals, experts, from different domains
	Work context	Virtual context	School, work, virtual contexts
Group goals and vision	Enhance the innovativeness and competitiveness of the organisation	Collective vision for solving real-life problems by innovating	Collective responsibility for addressing authentic problems
Conditions for knowledge creation	Intentionality, autonomy, fluctuation and creative chaos, redundancy, requisite variety	Intrinsic motivation, ethical integrity, knowledge accessibility, internal transparency, mutual trust	Self organisation favourable to 12 Knowledge Building principles (e.g., epistemic agency, collective responsibility)
Process of knowledge creation	Dialectic: tacit and explicit knowledge through socialisation, externalisation, combination, internalisation	Central leaders, rotating leadership, honest sentiment, balanced contribution, rapid responses, innovative language	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
Outcome of knowledge creation	Innovative products and solutions	Innovative products and solutions	Theories, models, designs, proposals – with some elaborated into innovative products and solutions

Source: First column adapted from Tan and Tan (2014)

2.5 Knowledge Building in education

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

2.5.1 Teaching practices

Knowledge Building uses an idea-centred, principle-based design approach to teaching (Hong and 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 cutting edge advances of other knowledge communities (*symmetric knowledge advancement*). Members take on high levels of *epistemic agency* for setting group goals, *democratising 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, synthesised to reach higher levels of understanding and coherence and to create increasingly powerful theories, designs, and artefacts (*rise above*).

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 et al., 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-organise into groups based on their interests and emergent goals.

For example, in a three-year study that explored evolving classroom practices of a Knowledge Building teacher, Zhang et al. (2009) found that flexible, adaptive social organisation 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 specialising in specific areas of inquiry, 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 based on emergent goals of the community; there were no fixed groups anymore. Students spontaneously and enthusiastically directed the course of their knowledge work with the teacher supporting 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-organised into emergent groups. 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, democratising knowledge* and *symmetric knowledge advancement*.

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).

2.5.2 Assessment practices

Assessment is key to informing teaching practices (van Aalst, 2013). The principle of *embedded, transformative assessment* implies that assessment is integral to Knowledge Building. Because Knowledge Building is nonlinear and non-scripted, assessment must align with the 12 Knowledge Building principles in a way that supports emergence and sustains collective progress (Scardamalia and 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 et al., 2006; van Aalst and 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 et al. (2012) developed the knowledge connections analyser that produces simple visualisations (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 visualise 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 et al. (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 specialised vocabulary in their online discourse. Hong et al. (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 of 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 et al. (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 Knowledge Building (Hong and 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) emphasises 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, we propose that the ideal idea-centred, principle-based assessment design would not only include social and semantic aspects, but also temporal aspects of Knowledge Building, to better uncover indicators of idea improvement. Toward this end, we propose a new method for examining collective cognitive responsibility.

In this study, we use social, temporal, and content analyses to examine collective cognitive responsibility in the grade 4 class from year 3 of Zhang et al.'s (2009) study. We expect rotating leadership to be an emergent phenomenon of this class, as students built knowledge within the opportunistic-collaboration model and self-organised into organic groups based on emergent goals, as in COINs. It is important to distinguish rotating leadership in COINs from forms of strategic rotation found in various organisational frameworks. What we aim to uncover in Knowledge Building is self-organisation 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 organisations (Nonaka and 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 and Campione, 1994; Palinscar and Brown, 1984).

2.6 Current study

2.6.1 Research questions

The current study is exploratory in nature, with the goal of applying COIN analyses of emergent community dynamics in a grade 4 Knowledge Building class. We hypothesised that if young students are really taking on high levels of collective cognitive responsibility and engaging in knowledge creation via self-organising processes, we would find rotating leadership as in COINs. We adopt the stance that a Knowledge Building classroom is a complex, adaptive system with multiple components interacting at multiple levels, thus we divided our research questions according to group and individual levels of analysis. Our research questions are as follows:

1. At the group level, do grade 4 students in a Knowledge Building class show rotating leadership? If they do, how many students assume leadership over the course of their Knowledge Building?
2. At the individual level, what is happening when a student is leading? What are different ways that leaders contribute to Knowledge Building discourse?

3 Methods

3.1 Context of study

3.1.1 Framework

In recognition of the complex, dynamic, iterative nature of knowledge creation, we adopted a mixed methods design (Greene et al., 1989) to seek elaboration, enhancement, and clarification of results from one method of analysis to the other. More specifically, we adopted a sequential approach to data analysis: social and temporal network analyses of online interactions to address the first question, and content analysis of online discourse to address the second question. Gloor's (2006) model of COINs provides a set of indicators (e.g., rotating leadership) for studying group creativity and productivity based on social network theory and Tsoukas (2009) and Sawyer's (2003b) dialogical approach to knowledge creation emphasises the importance of examining micro-interactions in dialogue for understanding how ideas grow and spread in a group.

By integrating existing quantitative and qualitative methods for studying innovation within organisational contexts, we expect to harness the strength of both types of analysis and gain deeper and fuller understanding of the phenomenon under study.

3.1.2 Sample and data

The study took place at the Dr. Eric Jackman Institute of Child Study of the University of Toronto, where Knowledge Building has been adopted for over a decade. The sample is a grade 4 class, comprising 22 students, who were experienced Knowledge Builders. The whole class engaged in the inquiry of optics over a three-month period: Light, How Light Travels, Colours of Light, Light and Materials, Natural and Artificial Light, Shadows, Images in our Eyes and in Films, and All We See Is Light. All classroom activities were designed around the Knowledge Building philosophy, and Knowledge Building technology was an integrated practice in the classroom. Students used Knowledge Forum (Scardamalia, 2004) extensively to document and improve one another's ideas – ideas that were elaborated and refined through observations, experimentation, and constructive use of authoritative sources. While Knowledge Building discourse took place in multiple media, Knowledge Forum served as the central workspace for idea development.

3.2 Data collection and analysis

3.2.1 Data source: Knowledge Forum

Knowledge Forum (Scardamalia, 2004) is a networked, collaboration platform designed specifically to support Knowledge Building community dynamics. Students share and visualise their ideas as notes; create 'build-on' notes to connect ideas; and create 'rise-above' notes to generate explanations and synthesise ideas. The online community space is synchronised between users in real-time, so that they can easily create, share, and improve their ideas. The environment has capabilities to support Knowledge Building discourse moves, such as scaffolds for theory building (e.g., "I need to understand...", "My theory is..."), co-authorship and annotation of notes, and the creation of higher level conceptual spaces to visualise 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).

3.2.2 Data analysis: multi-stage mixed-methods

Quantitative methods were employed in the first stage of data analysis. A list of content-related words (101 words) was compiled from the Ontario Curriculum of Science and Technology (Ontario Ministry of Education, 2007) to serve as the benchmark concepts in the community knowledge. The student discourse on Knowledge Forum was exported into KBDeX (Knowledge Building Discourse Explorer; Oshima et al., 2012), an analytic tool designed to facilitate content-based social network analysis for Knowledge Building discourse. Prior to analysis, each discourse unit (note) was spellchecked to normalise orthographical variations. For each co-authored discourse unit (note), a separate copy of the note was created for each individual author, in order to address the sharing of ideas among co-authors in the social network.

Qualitative methods were employed in the second stage of data analysis. We examined in-depth the class discussions surrounding the top 5 cases of leadership for each class, with a total of 15 cases examined.

More specifically, we conducted content analysis on the notes directly connected to the leader's notes in the note network – as well as notes (approximately ten notes) that occurred immediately before and after the leader's notes – in order to situate the student's influential contribution and their ideas within the wider context of the class discussion at that particular stage of their knowledge work.

3.2.3 Measures

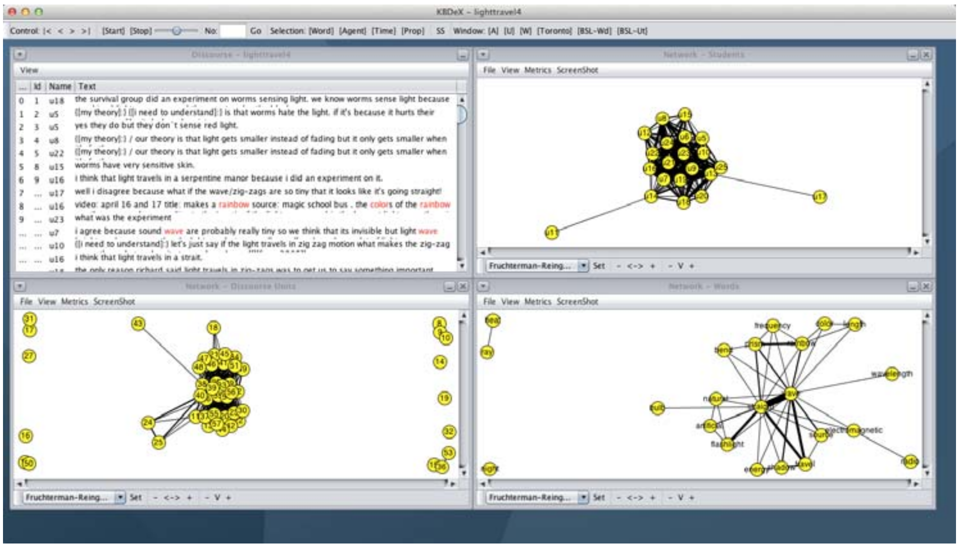
3.2.3.1 Semantic social network

The rotating leadership indicator used in this study employs an extension of social network analysis. Recall that Knowledge Building emphasises 'idea-centred' rather than 'task-centred' activity. Whereas in typical social network analysis, networks are created by the agents' social relationships (i.e., shared interactions via send/receive messages), networks for our analyses are created by the agents' semantic-social relationships (i.e., shared ideas via co-occurrence of words in discourse units). This specific method is crucial for our analyses because we used Knowledge Forum as the main source of data. In Knowledge Forum, students share their ideas by posting their note to a two-dimensional open working space; therefore we cannot trace send/receive interactions across multiple working spaces. Other studies have used co-occurrence of words via semantic analyses to assess knowledge advances (e.g., Hong and Scardamalia, 2014). An additional advantage of use of co-occurrence of words is that the form of connectedness becomes transparent to users, enabling teachers and students to examine semantic connections in the network with ease. Other techniques, such as latent semantic analysis (Landauer et al., 1998), hide the internal mechanisms for identifying semantic relationships. Analytic tools for Knowledge Building aim to make knowledge creation processes as transparent as possible to all users.

3.2.3.2 Network analysis method on KBDeX

The student discourse was imported into KBDeX in order to perform content-based social network analysis (Wasserman and Faust, 1994). KBDeX visualises three network structures using Knowledge Forum discourse as shown in Figure 1. These networks are created based on a bipartite graph of words x discourse units. The discourse unit network (bottom left, Figure 1) and the words network (bottom right, Figure 1) represent one-mode projections of the bipartite graph of words x discourse respectively. In other words, nodes in the discourse unit network will be connected if more than one word is shared between the two discourse units. Nodes in the word network will be connected if co-occurrence between the two words is found.

Figure 1 KBDeX window (see online version for colours)



The learners network (top right, Figure 1) is created based on words shared among learners' discourse units. Technically, nodes in the learners network will be connected if learners share more than one word in their discourse units. The thickness of the edge shows the strength of the connection between two learners, which is calculated by the number of discourse unit pairs shared for a particular word. In other words, the learners network shows the connection of the idea sharing between learners 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 learner in the learners network, then the discourse units authored by the selected learner will be highlighted in the discourse network; as well, the corresponding key words will be highlighted in the word network. This functionality was used during our analyses to investigate in depth specific stages of the inquiry process as a means to validate a learner's high betweenness centrality value based on results from the content-based social network analyses.

3.2.3.3 Temporal network analysis and time period

Our analysis method also relies on the 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 by the system in chronological order. When the user sets the time to ‘t’, the system will create a network using the discourse units from time 0 to ‘t’. The collection of the discourse units used in the time ‘t’ is defined as the following:

$$\{x \in S \mid x.time < t\}$$

By adding ‘t’ in the tool, an animation of how the network structure changes over time is displayed. In parallel, metrics of the network such as betweenness centrality (explanation below) were calculated for each udrt slice, and the tool shows a chart for the metrics on the timeline. Hence, the user can observe the metrics trajectory displaying changes as the discourse progresses along with pivotal points in the discourse where the value of the metric changes dramatically and a distinctive shape emerges.

In addition, this study used the ‘lifetime’ for discourse units, which sets the period of time to create the network. When a particular lifetime is set to the environment, the collection of the discourse units used in the time ‘t’ is defined as the following:

$$\{x \in S \mid (t - lifetime) < x.time \wedge x.time < t\}$$

For example, normally, at t = 120, the discourse units 0 to 120 are used to create the network, but if the user sets the lifetime to 50, at t = 120, only the discourse units 70 to 120 will be used 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 online discussion. On the other hand, the network structure without lifetime indicates the cumulative results of the Knowledge Building discourse.

We used the setting of lifetime 50 for our analysis. First, given the amount of writing that was produced on Knowledge Forum, we thought it was sufficient to capture rotating leadership using a short, focused time trend. Second, the number of the lifetime was set to approximately twice the number of learners; in our case, our sample was 22 students, so within a lifetime trend of 50, every student would have the chance to contribute at least two discourse units.

3.2.3.4 Betweennness centrality

Betweenness centrality measures the extent to which a member influences other members of the group (Gloor et al., 2003). 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.

Technically, betweenness centrality is a measure of the number of node pairs for which the shortest path between them passes through a selected node. The normalised betweenness centrality for a network with n nodes, for node i (Cb(i)), is given in the following:

$$C_b(i) = \frac{2}{(n-1)(n-2)} \sum_{i \neq j \neq k} \frac{g_{jk}(i)}{g_{jk}}$$

where g_{jk} is the summative of the shortest path from node j to k, and $g_{jk}(i)$ is the number of the shortest path that passes through node i.

At the group level, the centralisation of betweenness centrality is used to indicate the extent to which the network is centralised. The network is considered centralised when influence is not evenly distributed in the network (i.e., high influence is occupied by a few members of the network). A centralisation of betweenness centrality value of 1 means that the network is completely centralised, whereas a value of 0 means that the network is completely decentralised.

Technically, the centralisation of betweenness centrality (graph betweenness centrality) is a measure of the ratio of the summative of difference of max value in the network and each value, by the theoretical max value of the summative in the same node size of the network. The centralisation of betweenness centrality for a network with n nodes, Cb is:

$$C_b = \frac{\sum_{i=1}^{n} \left[C_b(i^*) - C_b(i) \right]}{max \sum_{i=1}^{n} \left[C_b(i^*) - C_b(i) \right]}$$

where $C_b(i^*)$ is the maximum value in the network, and *max* means theoretical maximum value. As the theoretical maximum value of the network with n nodes is given when it is the complete star network, Cb is:

$$C_b = \frac{2 \sum_{i=1}^{n} \left[C_b(i^*) - C_b(i) \right]}{(n-1)^2 (n-2)}$$

3.2.3.5 Rotating leadership indicator

Recent research in social network analysis shows that group productivity and creativity are indicated by not only a decentralised network structure with a strong leading core, but also rotating leadership, through oscillating patterns of betweenness centrality (e.g., Kidane and Gloor, 2007; Gloor et al., 2012; Gloor and Paasivara, 2013). During creative group processes, rotating leadership emerges, 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 success of the project is achieved by various contributors leading at various times.

We aimed to integrate the measure of rotating leadership in COINs with the concept of collective cognitive responsibility in Knowledge Building, by expanding the method of measuring rotating leadership as oscillation of the group betweenness centrality previously proposed by Gloor et al. We examined the leading student directly by using the chart depicting individual betweenness centrality (Figure 2). In fact, this chart shows the betweenness centrality of all students. We manually counted how many learners took a leading position (highest betweennness centrality) in this chart. A higher ratio of taking leadership means that the group work was accomplished collectively, whereas a lower ratio means that the group was managed by few strong leaders – perhaps one.

4 Results

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 develop leadership profiles.

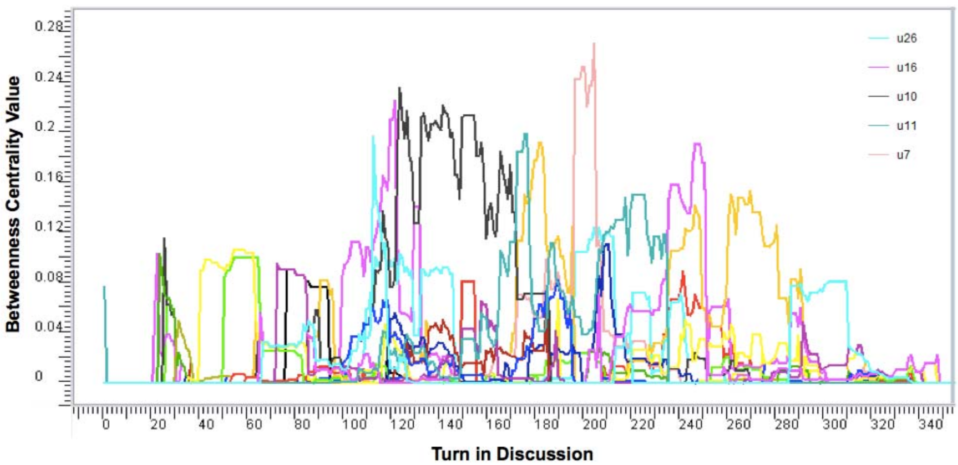
4.1 Stage 1: group level analyses (quantitative)

4.1.1 Social and temporal network analyses

First, we examined the extent to which the student network was centralised around specific members. We found that the average centralisation of betweenness centrality was relatively low, $m = 0.089$, $sd = 0.064$ (range = 0 to 0.26), which suggests that the student network was relatively decentralised, and students shared more or less the same level of influence in their network. Students maintained a relatively high cohesive network over time.

Next, we examined the betweenness centrality at the individual level as shown in Figure 2. The Y axis of the chart shows the betweenness centrality value, and the X axis shows the time. Each student is represented by a coloured line, resulting in a total of 22 lines displayed in the chart. The oscillation in colours of the overlapping lines depicts the phenomenon of rotating leadership, which means that the leading student (i.e., the student with the highest centrality at the time) changed frequently. Of the 22 students, 20 students took a leading position, suggesting that different students were leading across different times.

Figure 2 KBDeX visualisation of individual betweenness centralities across time (see online version for colours)



The legend in the top right of Figure 2 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 u7 (c_b = 0.27), student u10 (c_b = 0.24), student u16 (c_b = 0.23), student u26 (c_b = 0.20), and student u11 (c_b = 0.20). Student u7 had the greatest influence in the student network, and that student u10 had the longest duration of influence in the student network.

4.2 Stage 2: individual level analyses (qualitative)

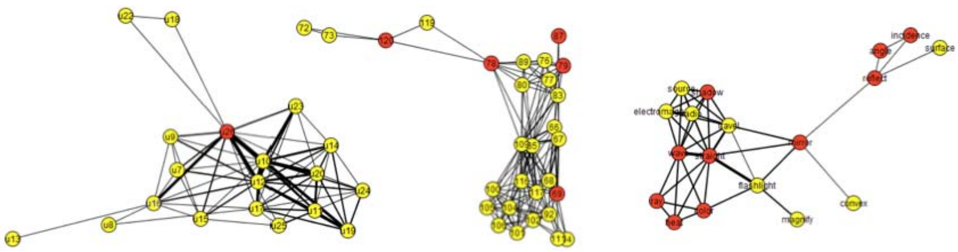
4.2.1 Content analyses

Follow up content analyses on the top five cases of betweenness centrality revealed that students with the highest betweenness centrality held a pivotal role in connecting diverse ideas from their peers with the whole-class discussion. Below we provide detailed depictions of these five cases in the order of their appearance so as to contextualise them within the progression of the whole-class discussion.

4.2.1.1 Case 1: student u26

The first case is student u26, who was leading between turns 113 to 118 and peaked at turn 112. The three networks in KBDeX are shown in Figure 3.

Figure 3 (a) Student network (b) Note network (c) Word network at turn 112, when student u26 had the highest betweenness centrality (see online version for colours)

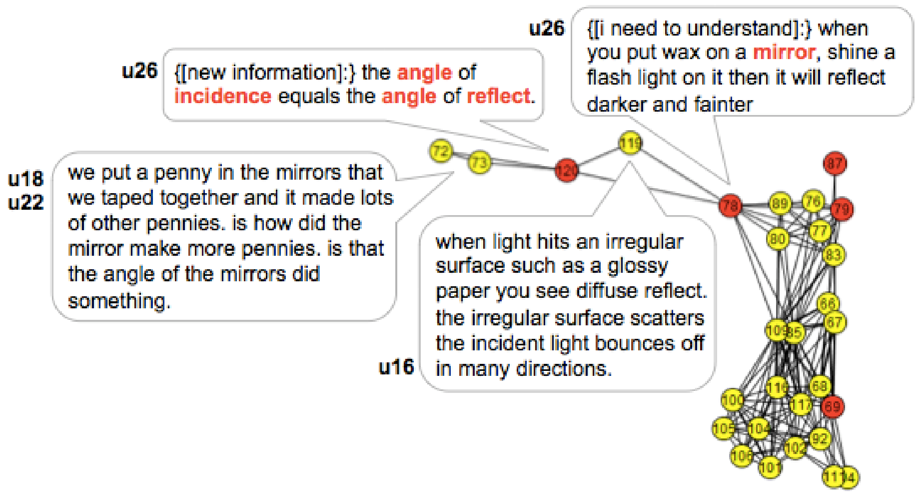


(a) (b) (c)

The student network in Figure 3(a) shows that student u26 connected students u18 and u22 to the larger group network. The note network in Figure 3(b) shows that notes 78 and 120, written by student u26, linked notes 72, 73, and 119 to the larger cluster of notes. The word network in Figure 3(c) shows that student u26 connected the concepts of ‘mirror’, ‘reflect’, ‘angle’, and ‘incidence’ to the main discussion of how light travels.

Figure 4 shows in detail how student u26’s notes played an important role in connecting ideas from their peers’ notes in the Lights and Materials view. The problem of understanding, as indicated in notes 72, 73, and 78, is how reflections are created from mirrors. Students u18 and u22 observed that taping objects to a mirror creates multiple reflections, while student u26 observed that that putting wax on a mirror makes light reflect more dimly. Student u16 suggested that the type of surface plays a role in how light is reflected and student u26 added that the angle in which light hits a surface directly relates to how light is reflected. Student u26’s notes connects students u18, u22, and u16’s notes to the larger discussion about how light travels, where other students were trying to understand whether light travels in a straight line or a wave.

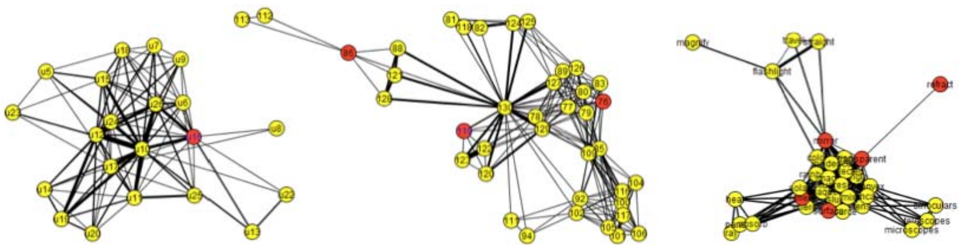
Figure 4 Contents from students u18, u22, u26, and u16’s notes in relation to the note network at turn 112 (see online version for colours)



4.2.1.2 Case 2: student u16

The second case is student u16, who was leading between turns 113 to 123 and peaked at turn 122. The three networks in KBDeX are shown in Figure 5.

Figure 5 (a) Student network (b) Note network (c) Word network at turn 122, when student u16 had the highest betweenness centrality (see online version for colours)

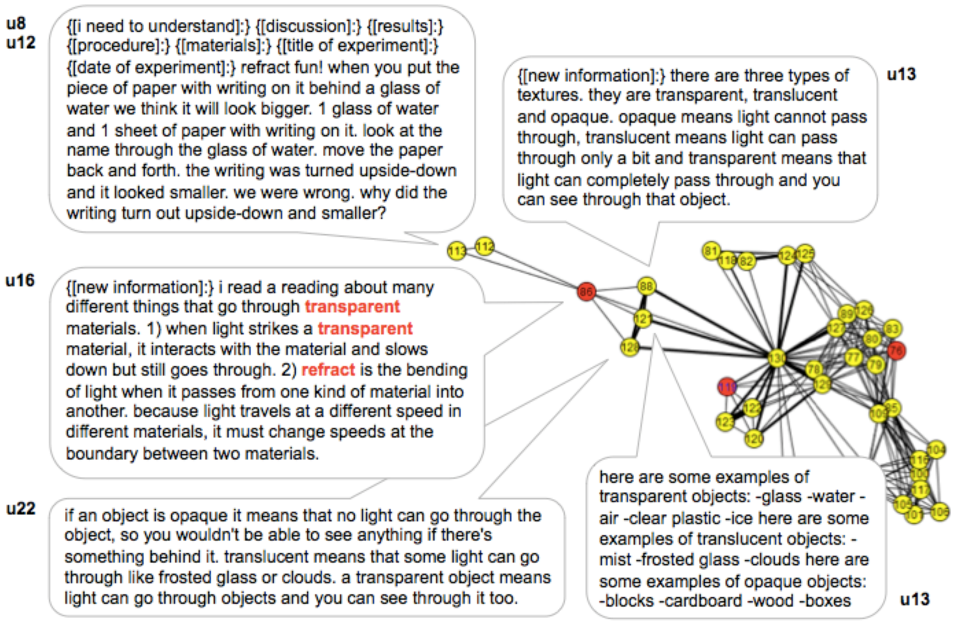


(a) (b) (c)

The student network in Figure 5(a) shows that student u16 connected students u8, u22, and u13 to the larger group network. The note network in Figure 5(b) shows that note 86 written by student u16, linked notes 112 and 113 to the larger cluster of notes. The word network in Figure 5(c) shows that student u16 connected the concepts of ‘transparent’ and ‘refract’ to the main discussion of how light travels.

Figure 6 shows in detail how student u16’s notes played an important role in connecting ideas from their peers’ notes in the Lights and Materials view. The problem of understanding, as indicated in notes 112 and 113 is refraction. Students u8 and u12 observed that the writing on a piece of paper was turned upside down when placed behind a glass of water. Student u16 explained that the speed of light decreases as it travels through transparent objects, and refraction occurs when the path of light travelling through an object is bent. Student u16's note connects students u8 and u12's notes to the larger discussion about how light travels through transparent, translucent, and opaque objects, where student u22 provided definitions and student u13 provided examples.

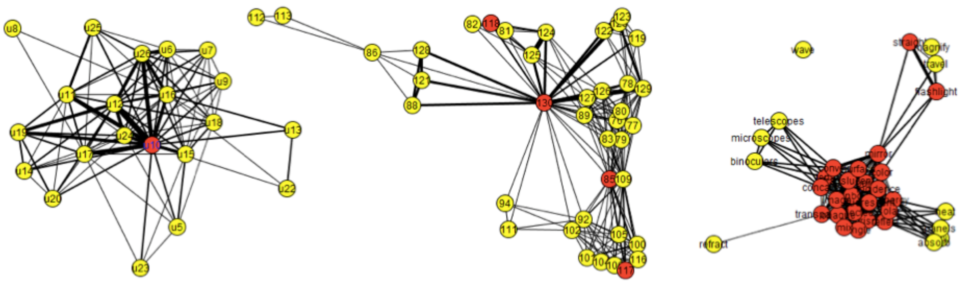
Figure 6 Contents from students u8, u12, u16, u22, and u13's notes in relation to the note network at turn 122 (see online version for colours)



4.2.1.3 Case 3: student u10

The third case is student u10, who was leading between turns 123 to 172 and peaked at turn 124. The three networks in KBDeX are shown in Figure 7.

Figure 7 (a) Student network (b) Note network (c) Word network at turn 124, when student u10 had the highest betweenness centrality (see online version for colours)



(a) (b) (c)

The student network in Figure 7(a) shows that student u10 took a central position in the larger group network. The note network in Figure 7(b) shows that note 130 written by student u10 was strongly linked to many notes in the larger cluster of notes. The word network in Figure 7(c) shows that student u16 connected many concepts to the main discussion of how light travels.

Figure 8 Contents from student u10's note in relation to the note network at turn 124 (see online version for colours)

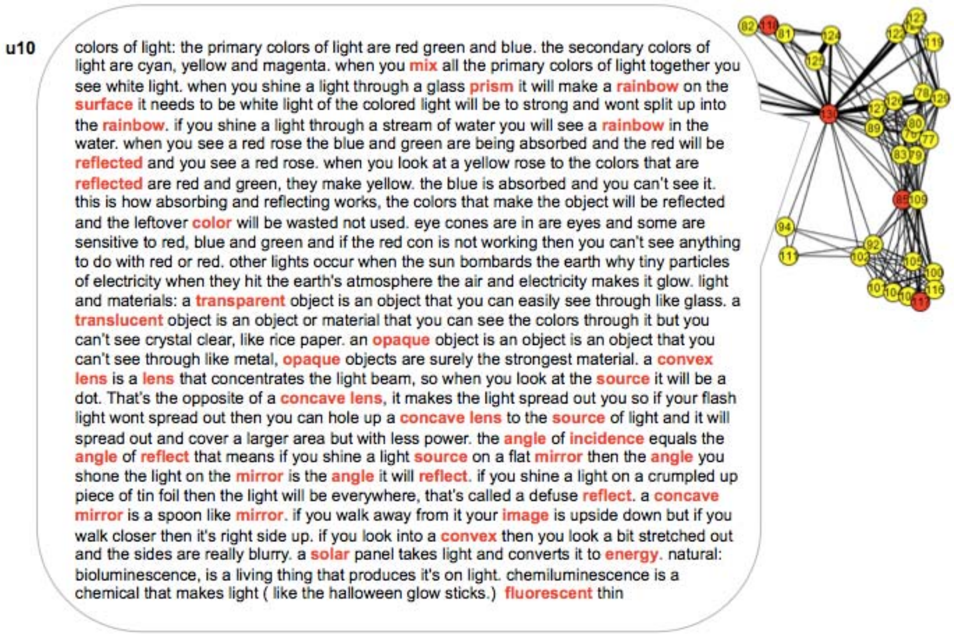


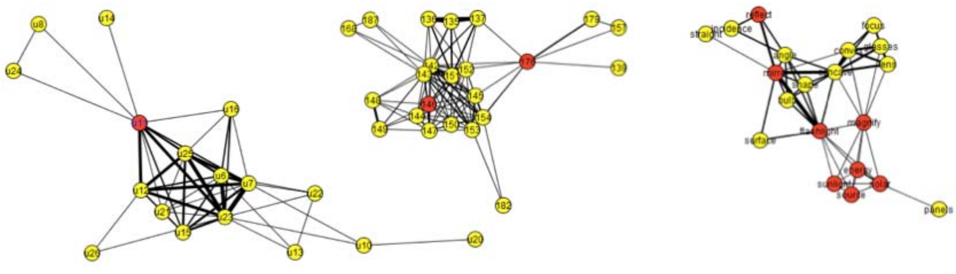
Figure 8 shows in detail how student u10's notes played an important role in connecting ideas from their peers' notes in the lights and materials view. The general problem of understanding, what is light and how light travels, is summarised in note 130. Student u10 discusses at length ideas surrounding rainbows and prisms; transparent, translucent, and opaque objects; convex and concave lenses; mirrors and reflection; and solar and chemical energy.

4.2.1.4 Case 4: student u11

The fourth case is student u11, who was leading between turns 166 to 178 and peaked at turn 175. The three networks in KBDeX are shown in Figure 9.

The student network in Figure 9(a) shows that student u11 connected students u24, u8, and u14 to the larger group network. The note network in Figure 9(b) shows that note 176 written by student u16, linked notes 179, 157, and 139 to the larger cluster of notes. The word network in Figure 9(c) shows that student u16 connected the concepts of 'sunlight', 'solar energy', and 'flashlight' to the main discussion of lenses and magnifying glasses.

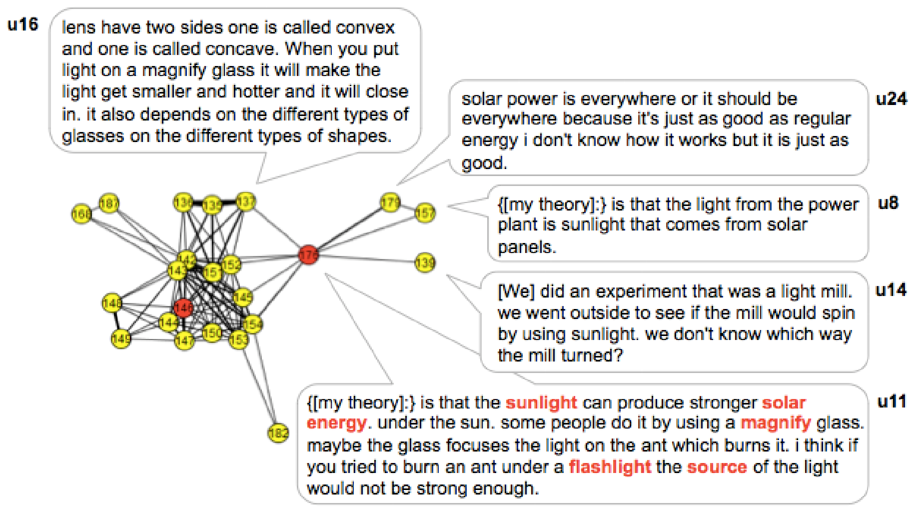
Figure 9 (a) Student network (b) Note network (c) Word network at turn 175, when student u11 had the highest betweenness centrality (see online version for colours)



(a) (b) (c)

Figure 10 shows in detail how student u11's note 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 notes 179 and 157 is light as an energy source. Student u24 raised a question about how solar energy works, while student u8 shared their theory about solar panels, and student u14 described their experiment about light mills. Student u11 added their theory about how the source of light would relate to its strength of energy. Student u11 hypothesised 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 u11's note connects students u24, u8, and u14's notes to the larger discussion about lenses and magnifying glasses, where student u16 explains how different types of lenses and glasses adjust the strength of light.

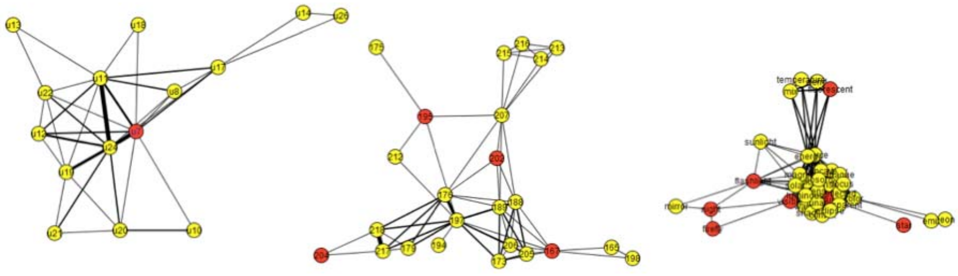
Figure 10 Contents from students u24, u8, u14, and u11's notes in relation to the note network at turn 175 (see online version for colours)



4.2.1.5 Case 5: student u7

The fifth case is student u7, who was leading between turns 197 to 207 and peaked at turn 205. The three networks in KBDeX are shown in Figure 11.

Figure 11 (a) Student network (b) Note network (c) Word network at turn 205, when student u7 had the highest betweenness centrality (see online version for colours)

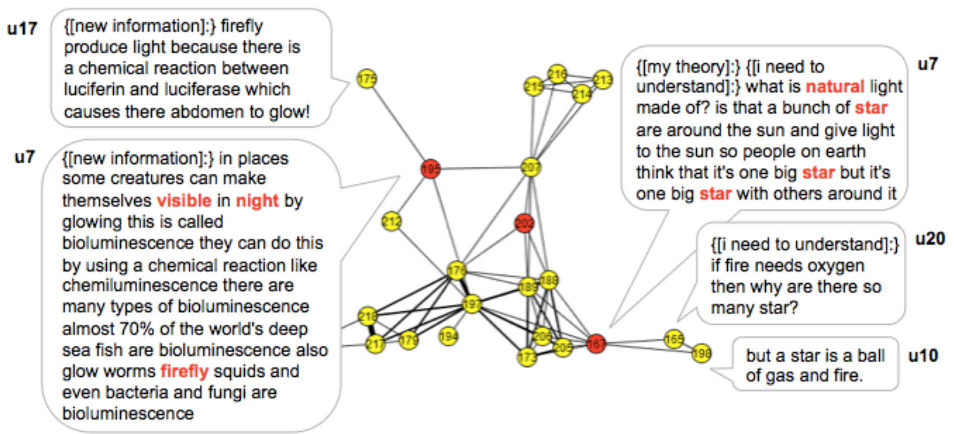


(a) (b) (c)

The student network in Figure 11(a) shows that student u7 connected students u20, u10, and u17 to the larger group network. The note network in Figure 11(b) shows that notes 195 and 167 written by student u16, linked notes 175, 165, and 198 to the larger cluster of notes. The word network in Figure 11(c) shows that student u16 connected the concepts of 'night', 'star', and 'firefly' to the main discussion of sources of light.

Figure 12 shows in detail how student u7's note 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 167 is natural sources of light. In one discussion thread, student u7 raised the question of what natural light is made of and hypothesised that natural light comes from both the sun and stars. Students u20 and u10 tried to understand the relationship between stars, fire, oxygen, and gas. In another discussion thread, student u17 explained how fireflies glow, and student u7 added that bioluminescence helps other living things, such as worms, fish, squids, and bacteria glow. Student u7's note connects students u17, u20, and u10's notes to the larger discussion about sources of light, where other students compare and contrast artificial and natural sources of light.

Figure 12 Contents from students u17, u7, u20, and u10's notes in relation to the note network at turn 205 (see online version for colours)



5 Discussion

The goal of this study was to explore collective cognitive responsibility via rotating leadership in a Knowledge Building classroom. Our results indicate that almost all students, 20 out of the 22, were leaders over the course of explorations in the field of optics – explorations that engaged them in issues of rainbows and prisms; transparent, translucent, and opaque objects; convex and concave lenses; mirrors and reflection; and solar and chemical energy. When students took a leadership position, they were introducing new ideas and seeking coherence between existing ideas in the community. Of the five cases we examined, four students incorporated new concepts into the community discourse. In the fifth case we examined, one powerful note was produced by a single student, who remained influential for the longest period of time. Taken together, these five leaders contributed to the advancement of the community knowledge in meaningful ways, based on the Knowledge Building principles. They took on high levels of *epistemic agency* by connecting *diverse ideas* together, all the while *democratising knowledge* by bringing these new ideas from small groups into the context of the large group discussion; by enriching the class discussion as a whole, they supported *symmetric knowledge advancement* of the small groups.

Our findings confirm our hypothesis that rotating leadership can be found in a grade 4 Knowledge Building class in which participants are assuming *collective responsibility* for *idea improvement* and taking a principle-based approach to knowledge creation. Recall that this is the year 3 case from Zhang et al.'s (2009) study, where students collaborated in opportunistic, emergent groups. They experienced the highest levels of knowledge diffusion and made the greatest knowledge advances. The students in this Knowledge Building community exemplify the Knowledge Building principles of *epistemic agency, idea diversity, idea improvement, collective responsibility, democratising knowledge,* and *symmetric knowledge advancement*.

5.1 Limitations

As this is the first case of applying rotating leadership to a Knowledge Building context, our findings are exploratory and descriptive in nature, opening the possibility of future work in this area and raising several issues that need to be addressed.

The first set of issues surrounds the methods used for of our study. It should be noted that we adapted Gloor's (2006) original method of social network analysis to our specific context of Knowledge Building. We chose to incorporate social, semantic, and temporal aspects together via content-based social and temporal network analyses in order to develop a more idea-centred approach for assessing Knowledge Building. Thus, student networks are formed based on shared use of key concepts in the community knowledge rather than send-receive interactions.

Regarding the analytic tool we 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 needed to be spellchecked manually and word lists needed to be 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 KBDeX automated data preparation; for example, spellchecking notes as Knowledge Forum data is exported, adding a key word dictionary/thesaurus component, providing word families to identify simple word variations, and incorporating an annotation feature on top of the network visualisations. 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 grades 1 to 8 Ontario science curriculum. Future comparisons of content-based social network analyses with variations of content-based word lists may affect the emergence of rotating leadership in Knowledge Building.

Regarding the analytic methods we employed for assessing the social-semantic interactions, only specific behaviours could be identified, but not intentions and 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 our study across other Knowledge Building communities in different social, linguistic, and cultural contexts.

The second set of issues surrounds the sample of our study and the generalisability of our results. From the perspective of Kurt Fischer's theory of cognitive development (Fischer and 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 teacher was committed to Knowledge Building practice and the third of a three-year effort to improve Knowledge Building practices was used as the basis for this exploration. Moreover, the school is committed to the Knowledge Building philosophy; for that reason, most of the students in the study entered grade 4 with years of experience in a school culture that emphasised 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. Current research is extending this work to a grade 1 context in the same school, and results look promising. At the same time, we are identifying 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.

Finally, future research should explore the practical implications of rotating leadership in school-based Knowledge Building communities. 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-organisation, and rotating leadership? How can rotating leadership be used for group- and individual-level assessment? How can rotating leadership be sustained in order to support continual idea improvement and pervasive Knowledge Building in the classroom?

5.2 Implications

While previous work has compared knowledge creation with Knowledge Building, no study has compared COIN with Knowledge Building. Our study demonstrates that rotating leadership appears to be an emergent phenomenon of a Knowledge Building community. Coherent findings from two different fields – organisational management and education – support theoretical assumptions of each: for Knowledge Building that it supports work as found in knowledge-creating organisations, and for COIN that rotating leadership taps a generalisable phenomenon of innovative teams. In combination they open up new space for exploration of innovative knowledge communities.

Knowledge Building classrooms operate in a COIN fashion – dynamic, decentralised networks, where control is continuously shifted between members. It is striking that a teacher who shares his decision-making power with students – students as young as 8 years of age – finds them capable of self-organising and collaborating through opportunistic engagement and achieving their collective goal for advancing knowledge. In this case, opportunistic collaboration and the continuous reorganisation of groups are considered a critical factor for the success of this Knowledge Building community (Zhang et al., 2009). Our study adds that rotating leadership is an emergent phenomenon in the successful Knowledge Building community. 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.

Our new method for visualising collective cognitive responsibility 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 visualisation 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 et al., 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. Another promising line of research would be to integrate the six honest signals of COINs (Gloor, 2006) with existing and new Knowledge Building measures (e.g., van Aalst, 2012; Philip, 2010; Sun et al., 2010; Hong and Scardamalia, 2014; Hong et al., 2015; Chen 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 specialised vocabulary; informal research in Knowledge Building indicates that the principle of *idea diversity* is reflected in entry of unique terms, assessed through a vocabulary-growth measure available in Knowledge Forum analytic tools. That said, our assessment method should be used with discretion. We would not recommend using rotating leadership as a prescriptive benchmark for standardising the group process – the goal is not to compare and compete for leadership – instead, we believe it would be more beneficial to use rotating leadership as a descriptive indicator of group creativity and to find ways for the group to monitor their progress as work proceeds. Under such conditions, perhaps the two students who did not assume a leadership role would have found the opportunity to do so.

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. Knowledge Building represents one way to move education from the margins to the centre 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. We believe that Knowledge Building has the potential to democratise 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 et al., 2012).

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