Community Knowledge, Collective Responsibility: The Emergence of Rotating Leadership in Three Knowledge Building Communities

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Abstract: Developing cultural capacity for innovation is an educational imperative. The challenge in schools is to foster a culture of sustained, creative work with ideas, as in out-of-school Collaborative Innovation Networks (COINs) and cyberteams that self-organize to create knowledge. In this study, we examined the online knowledge work of three Knowledge Building classes, where young students assumed collective responsibility for creating and improving their community knowledge. We adopted the COIN concept of rotating leadership to visualize collective responsibility for knowledge advancement. Using a mixed methods approach, we conducted social and temporal network analyses, then content analyses of student notes to further assess cases of student leadership. Overall, we found relatively decentralized student networks, with most students leading the group at different points in time; when leading, students were connecting unique ideas to the larger class discussion. We discuss our findings within the context of designing embedded, transformative assessment for knowledge building communities.

Keywords: Knowledge Building; Collaborative Innovation Network; collective responsibility; rotating leadership; self-organization; knowledge creation; innovation

Introduction

To prepare students for a world of constant change (Takeuchi & Nonaka, 1986) within innovation-driven societies (OECD, 2010), many 21st century education movements (e.g., Johnson, 2009; Ananiadou & Claro, 2009) aim to equip students with skills in creativity, critical thinking, collaboration, and communication. Apart from changing curricular goals, however, most classroom activities continue to be teacher-directed, with students being assessed individually against traditional benchmarks (Griffin, McGraw, & Care, 2012). Such fixed structures and processes prevent innovation, adaptability, and new competencies from emerging in schools (Sawyer, 2015; Scardamalia et. al., 2012). One way to address educational challenges of the 21st century is by exploring innovative organizational configurations for knowledge creation in schools (Bereiter, 2002; Sawyer, 2006; Philip, 2011).

Knowledge Building, which is synonymous with knowledge creation (Scardamalia & Bereiter, 2014; Bereiter & Scardamalia, 2014), represents a longstanding effort at building cultural capacity for innovation. It aims to transform education into a knowledge-creating enterprise by creating a culture of innovation in classrooms and engaging students directly in sustained, creative work with ideas, so that students are engaged continuously in creating knowledge of value to the community (Scardamalia & Bereiter, 2003). From a young age, students are empowered to take ownership of their learning through participation in high-level decision processes, so that all share collective responsibility for advancing the community goals (Scardamalia, 2002).

In contrast to many activity-centered and procedure-based constructivist pedagogies, Knowledge Building uses an idea-centered, principle-based design approach (see Scardamalia, 2002 for overview of 12 principles). For example, the principles of *idea diversity, improvable ideas*, and *rise above* prioritize students' ideas at the center of class interactions and highlight the iterative nature of idea generation, refinement, and invention in knowledge creation processes that enhance the breadth and depth of group understanding and achievement. Principles of *epistemic agency*, *democratizing knowledge,* and *community knowledge, collective responsibility* create contexts for empowering students to take charge of knowledge creation processes at the highest level, including defining problems, setting goals, contributing to and monitoring goal progress, synthesizing advances at new and unexpected levels, and more generally, giving priority to knowledge creating interactions as cultural practices (Bereiter & Scardamalia, 2014). In a successful Knowledge Building classroom, the teacher and students embody all twelve principles as they work collaboratively toward creating community knowledge. The teacher supports student agency and autonomy by facilitating improvisation in their own practice through opportunistic collaborative engagement (Zhang et. al., 2009), wherein the teacher encourages students to self-organize into small groups based on emergent goals of the community. Similarly, Collaborative Innovation Networks (COINs; Gloor, 2006), which create knowledge and drive innovations around the world, function based on principles of autonomy and self-organization. Whereas highly productive teams have stable leaders, COINs operate in a decentralized fashion with various emergent leaders rotating leadership over the course of a project (Gloor et. al., 2003; Kidane & Gloor, 2007). Members share collective responsibility for their knowledge work through a high degree of connectivity, interactivity, and sharing (Gloor, 2006). The idea-centered, principle-based design approach to Knowledge Building pedagogy emphasizes the role of self-organization in knowledge creation and innovation (Hong & Sullivan, 2009; Scardamalia & Bereiter, 2014), which is consistent with how COINs operate.

Because the Knowledge Building process is emergent and non-linear, assessment designs must complement the 12 Knowledge Building principles in a way that supports and sustains collective progress, as indicated by the principle of *concurrent, embedded, and transformative assessment*. Previous work aimed at developing principle-based indicators of collective responsibility for community knowledge advancement used descriptive statistics (e.g., van Aalst et. al., 2012) to assess online reading and writing behaviours and social network analyses (e.g., Philip, 2010) to assess collaboration patterns within the community. Additionally, semantic measures (e.g., Hong et. al., 2015) and lexical measures (e.g., Sun, Zhang, & Scardamalia, 2010) were developed to assess the diffusion of ideas within the community and the growth of community knowledge over time. While quantitative measures are useful for capturing patterns of social interactions and community connectedness, qualitative analyses are useful to assess the quality and coherence of ideas, concepts, and theories shared between students. Thus, in designing Knowledge Building assessments, it is important to integrate social network analyses with content analyses in order to understand the complex process of collaborative meaning making (van Aalst, 2012). We further add that the ideal assessment would integrate social, semantic, and temporal aspects of Knowledge Building.

The current study is exploratory in nature, with the goal of developing a new method to assess collective responsibility for knowledge advancement in three Knowledge Building classes. We hypothesized that if young students are really taking on collective responsibility and self-organizing to create community knowledge, we would find rotating leadership as an emergent phenomenon of these classes, as in COINs. In adopting the stance that a Knowledge Building class is a complex, self-organizing system with multiple components interacting at multiple levels, we created two sets of research questions which corresponded to two levels of analyses:

1. At the group level, what does rotating leadership look like in the Knowledge Building class? How many students emerge as leaders over the course of the inquiry?
2. At the individual level, what is happening when a student is leading? How are they contributing to the group discourse?

Methods

In recognition of the complex and dynamic nature of the Knowledge Building process, we adopted a complementary mixed methods design (Greene, Caracelli, & Graham, 1989) in order to harness the strengths of quantitative and qualitative analyses and develop a more holistic understanding of the phenomenon under study: collective responsibility for knowledge advancement. We used quantitative methods (i.e., social and temporal network analyses of online interactions) to address the first sets of questions, and we used qualitative methods (i.e., content analyses of online discourse) to address the second sets of question.

Data sources

Our samples consisted of Knowledge Building classes at the Dr. Eric Jackman Institute of Child Study participating in Beyond Best Practice and Ways of Contributing research projects (2002-2012) located in Toronto, Canada. In order to test our hypothesis, we selected successful Knowledge Building classes and conducted secondary analysis to validate a new method of assessment. We selected classes in which 1) students engaged in 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. Knowledge Forum (Scardamalia, 2004) is an online community space optimized to support knowledge creation processes. Students contribute ideas as notes in conceptual spaces called views; connect ideas with "build-on" notes; and generate explanations/syntheses with "rise-above" notes. Student work in Knowledge Forum involves continuous reading, writing, and revising of notes to advance the community knowledge. In summary, Case 1: Grade 4 light consisted of 22 students 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. Case 2: Grade 1 water consisted of 21 students 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. Case 3: Grade 4 rocks consisted of 23 students 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. See Table 1 for summary of three cases.

Data analyses

The first stage of analysis involved quantitative methods. Student notes in Knowledge Forum were spellchecked and exported into KBDeX (Knowledge Building Discourse Explorer; Oshima, Oshima, & Matsuzawa, 2012) in order to facilitate social and temporal network analyses based on a list of content-related words extracted from the Ontario Curriculum of Science and Technology, which served as benchmark concepts in the community knowledge. KBDeX produces network visualizations of the learners network, notes network, and words network based on the co-occurrence of key words in each network, with the thickness of edges representing the strength of connections. For example, the learners network shows idea sharing across learners, the notes network shows idea overlap across notes, and the word network shows how ideas are connected in the community knowledge as the group discussion unfolds. KBDeX also produces temporal visualizations of network metrics, such as betweenness centrality, which indicates the extent to which a member influences other members of the group (Gloor et. al., 2003). Whereas a betweenness centrality value of 1 means that a member is highly influential, a value of 0 means that a member is equally influential as other members. In using KBDeX, we were able to explore the three networks seamlessly in order to examine stages of the inquiry when a specific learner had high betweenness centrality, as indicated by the emergent peaks in the temporal visualization (see Figure 1). For example, when we selected a specific learner in the learners network, their corresponding notes were highlighted in red in the discourse network, and their corresponding keywords were highlighted in red in the word network (see Figures 2a, 2b, 2c respectively). The second stage of analysis involved qualitative methods. After identifying leaders with a betweenness centrality value of 0.20 or higher, we used KBDeX to explore the three networks in order to understand the discursive context that supported their emergence as the leader: 1) which students shared the same ideas as this specific leader, 2) which notes contained the same ideas as this specific leader's notes, and 3) which ideas this specific leader connected together. More specifically, the note network allowed us to conduct content analyses on notes immediately connected to that specific leader; we interpreted notes isolated from this network as student efforts directed toward diverse and unique ideas in the community knowledge. By tracing and comparing changes in the network shapes across different times, we were able to identify pivotal points in the group discourse that led to greater connectedness of ideas (i.e., explanatory coherence), which we interpreted as knowledge advancement. Below, we present one leader (i.e., influential student) from each Knowledge Building case.

Findings

Table 1 shows descriptive measures to assess Knowledge Building in all three cases. Network measures for reading and writing behaviours, such as average weighted degree (AWD), transitivity, average path length (APL), and average betweenness centrality (ABC), indicate that students were working productively in Knowledge Forum for each case. Overall, reading networks are denser than build-on networks, suggesting that students read more of their peers' notes than they did build on them. In the section below we present our findings for each Knowledge Building case from general to specific: rotating leadership at the group level, followed by a detailed account of what happened when a particular student was leading. For each case, we present our results in the following order: temporal analyses, network analyses, content analyses.

Table 1. Descriptive measures of student activities in Knowledge Forum for Cases 1, 2, and 3

Sample	Students	Notes	Network	Density	AWD	Transitivity	APL	ABC
Case 1: Grade 4 light	22	380	Reading Building-on	1.03 0.17	43.36 7.27	1.00 0.42	1.02 2.24	20.02 23.57
Case 2: Grade 1 water	21	391	Reading Building-on	0.76 0.26	31.82 10.82	0.91 0.57	1.29 2.16	19.04 28.25
Case 3: Grade 4 rocks	23	269	Reading Building-on	0.96 0.25	40.18 10.54	0.99 0.55	1.05 2.21	22.90 26.49

Case 1: Grade 4 light

Figure 2 shows 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 lines depicts the phenomenon of rotating leadership, which means that the leading student (i.e., the student with the highest betwenness centrality) changed frequently. Of the 22 students, 20 students took a leading position, suggesting that many students were influential at different times. The legend in the top right of Figure 2 indicates the colour of student 11, who was leading between turns 166 to 178, and peaked at turn 175 (betweenness centrality = 0.20).

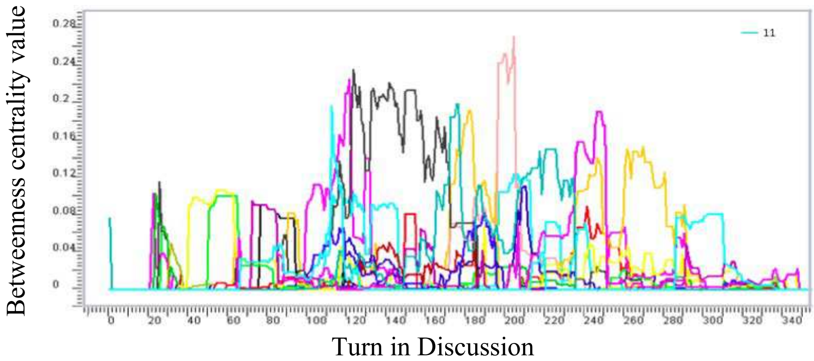

Figure 1. Temporal visualization of betweenness centrality of Case 1: Grade 4 light.

Figure 2 shows network analyses in KBDeX when student 11 was leading at turn 175. The student network in Figure 2a shows that student 11 connected students 24, 8, and 14 to the larger group network. The note network in Figure 2b shows that note 176 written by student 11, linked notes 179, 157, and 139 to the larger cluster of notes. The word network in Figure 2c shows that student 11 connected the concepts of "sunlight", "solar energy", and ''flashlight'' to the main discussion of lenses and magnifying glasses.

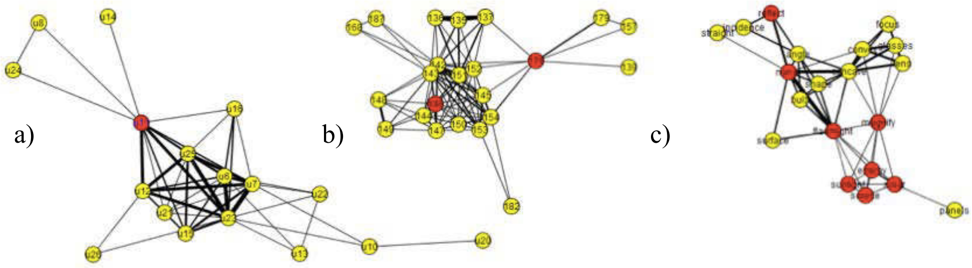

Figure 2. Network visualizations at turn 175: a) student network, b) note network, and c) word network.

Below is an excerpt of the discussion where student 11 played an important role in connecting ideas from their peers' notes in the Natural and Artificial Light view. The problem of understanding, as indicated by student 24, is light as an energy source. Student 24 raised a question about how solar energy works, while student 8 shared their theory about solar panels, and student 14 described their experiment about light mills. Student 11 added their theory about how the source of light would relate to its strength of energy. Student 11 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 11's note connects student 24, 8, and 14's notes to the larger discussion about lenses and magnifying glasses, where student 16 explains how different types of lenses and glasses adjust the strength of light.

Student 24:	solar power is everywhere or it should be everywhere because it's just as good as regular energy i don't know how it works but it is just as good.
Student 8:	[My theory]: is that the light from the power plant is sunlight that comes from solar panels.
Student 14:	[We] did an experiment that was a light mill. we went outside to see if the mill would spin by using sunlight. we don't know which way the mill turned?
Student 11:	[My theory]: is that the sunlight can produce stronger solar energy. under the sun. some people do it by using a magnify glass. maybe the glass focuses the light on the ant which burns it. i think if you tried to burn an ant under a flashlight the source of the light would not be strong enough.

Student 16: lens have two sides one is called convex and one is called concave. When you put light on a magnify glass it will make the light get smaller and hotter and it will close in. it also depends on the different types of glasses on the different types of shapes.

Case 2: Grade 1 water

Figure 3 shows temporal analysis of betweenness centrality for Case 2. Of the 21 students, 12 students took a leading position, suggesting that half the students were influential at different times. The legend in the top right of Figure 3 indicates the colour of student 195251, who was leading between turns 147 to 209, and peaked at turn 161 (betweenness centrality = 0.22).

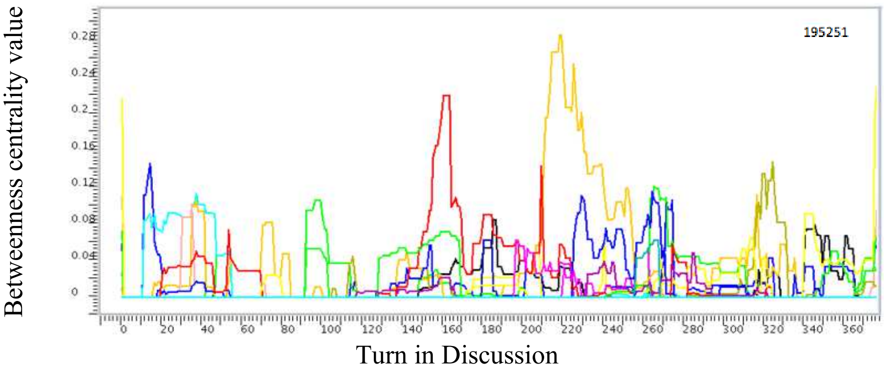

Figure 3. Temporal analysis of betweenness centrality of Case 2: Grade 1 water.

Figure 4 shows network analyses in KBDeX when student 195251 was leading was leading at turn 209. The student network in Figure 4a shows that student 195251 connected students 1044599, 1852393, and 1162041 to the larger group network. The note network in Figure 2b shows that note 183 written by student 195251, linked notes 181, 177, and 211 to the larger cluster of notes. The word network in Figure 2c shows that student 195251 connected the concepts of "space", "atmosphere", and "air" to the main discussion of cloud and evaporation.

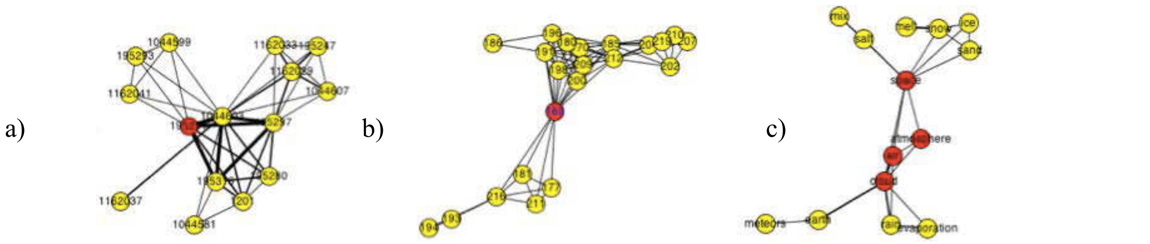

Figure 4. Network visualizations at turn 209: a) student network, b) note network, and c) word network.

Below is an excerpt of the discussion where student 195251 played an important role in connecting ideas from their peers' notes in the All About Water view. The problem of understanding, as indicated by student 1162041, is whether or not there is water in space. Student 1162041 raised a question about where water goes in space, while student 185293 wondered about water from space mixing with salt on earth and student 1044599 shared their theory about water coming from space. Student 195251 added their theory about how the atmosphere stops clouds (and by extension, water) from entering space. Student 195251 hypothesized that since there is no air in space, there are no clouds (and by extension, water) in space. Student 195251's note connects student 1162041, 1852393, and 1044599's notes to the larger discussion about clouds, water, and evaporation, where student 195313 observed that you cannot see water in a cloud.

Student 1162041: [I wonder]: if water is in space where does it go

Student 185293: [I wonder]: if water came from space and mix with salt on the ground?

Student 1044599: [My theory]: it could have came from space

Student 195251: [My theory]: there is no air in space and cloud are air and i think that the atmosphere will stop it so the air can't go

Student 195313: inside a cloud the only color you see is white and you can't see water in it

Case 3: Grade 4 rocks

Figure 5 shows temporal analysis of betweenness centrality for Case 3. Of the 23 students, 11 students took a leading position, suggesting that half the students were influential at different times. The legend in the top right of Figure 3 indicates the colour of student 379, who was leading between turns 172 to 190, and peaked at turn 173 (betweenness centrality = 0.21).

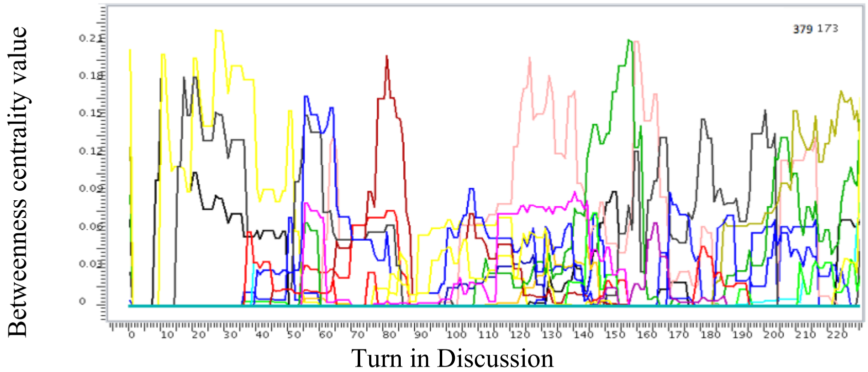

Figure 5. Temporal analysis of betweenness centrality of Case 3: Grade 4 rocks.

Figure 6 shows network analyses in KBDeX when student 379 was leading at turn 173. The student network in Figure 6a shows that student 379 connected students 398, and 434, 277 to the larger group network. The note network in Figure 2b shows that note 128 written by student 379, linked notes 147, 145, and 144, to the larger cluster of notes. The word network in Figure 6c shows that student 379 connected the concepts of "atoms" to the main discussion of human life on the planet.

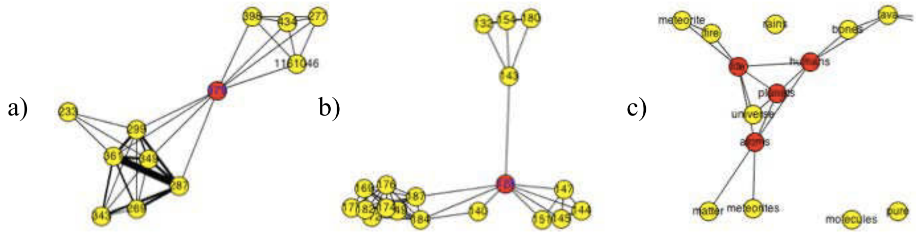

Figure 6. Network visualizations at turn 173: a) student network, b) note network, and c) word network.

Below is an excerpt of the discussion where student 379 played an important role in connecting ideas from their peers' notes in the Rocks and Minerals view. The problem of understanding, as indicated by students 277 and 434 is the relation between atoms and matter. Student 277 raised a question about the composition of atoms while student 398 referred to an authoritative source about atoms and earth, and student 434 provided information that atoms are made of electrons, nucleus, and other matter. Student 379 added their theory about how atoms and matter relate to the big bang and life on earth. Student 379 hypothesized that atoms collided to form planets, which allowed for life to evolve on planet earth. Student 379's note connects student 277, 398, and 434's notes to the larger discussion about life on planets, where student 361 initiated the inquiry of how life first came to planet earth.

Student 277: what are atoms made of??????????????????????????????????

Student 398: i think the earth formed by lots of atoms but like in the movie we watched earth the biography it showed lots of meteorites joining together.

Student 434: yes. matter is smaller than atoms. that's what atoms are made of. matter is electrons, nucleus, and a lot more that i don't know about

Student 379: [A better theory]: is that it is a place where atoms collided and formed planets. then life form came and it evolved to the life forms you see today. that is how humans came to be.

Student 361: [I need to understand]: how did life first come to earth? (after the big bang) i thought that the earth was made out of fire until it cooled down by a icy meteorite.

Conclusions and implications

This study aimed to adopt the COIN concept of rotating leadership as a new method for visualizing collective responsibility for knowledge advancement. Our findings demonstrate that rotating leadership, as indicated by oscillating patterns of betweenness centrality, is an emergent phenomenon in Knowledge Building classes, where students work collaboratively to create community knowledge while receiving appropriate pedagogical and technological supports. In Case 1: grade 4 light, 20 of 22 students were leaders. In Case 2: grade 1 water, 12 of 21 students were leaders. In Case 3: grade 4 rocks, 11 of 23 students were leaders. When students were leading, they were generating new theories by connecting their peers' unique ideas with the larger class discussion, thus demonstrating principles of *epistemic agency, idea diversity, improvable ideas, rise above,* and *community knowledge, collective responsibility*. It is interesting to note that in all three cases, in addition to having leaders who rotate frequently, multiple leaders appeared to emerge simultaneously. Further analyses are needed to understand leadership dynamics with multiple, "shared" leaders, seemingly engaged in symmetric, mutually supportive advances. COIN theory (Gloor, 2006) suggests that having a strong core with several overlapping leaders is conducive to group creativity and productivity, thus the "sharing" of rotating leadership may also be beneficial for the Knowledge Building community as a whole.

Future work on Knowledge Building assessments should aim to verify our findings across various learning contexts (e.g., learner's age, subject matter, school culture). KBDeX represents a powerful analytic tool for providing formative feedback during Knowledge Building (e.g., Matsuzawa et. al., 2012, Resendes et. al., 2015). We believe that rotating leadership has the potential to serve as a descriptive measure for teachers and students to assess and monitor group progress as their creative work proceeds, and ultimately help sustain innovative interactions in the 21st century classroom.

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