Dynamics of Promisingness Judgments in Knowledge Building Work of 8- to 10-Years-Olds*

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Abstract: The ability to identify promising ideas is an important but under-explored aspect of knowledge building. This study examines the dynamics of promisingness judgments in knowledge-building discourse by young students. To this end, we implemented a design experiment—with both pedagogical and technological interventions—in a Grade 3 class and engaged them in judging promisingness of their ideas in three science units over two consecutive years. Analysis of individual profiles identified five main characteristics of young students' judgments. Detailed analysis of student discourse uncovered both successful and improvable group practice of promisingness judgments among students. These results will inform future classroom innovations to support promisingness evaluation by young students.

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Objectives

This paper reports first steps in a program of research that seeks to explore the extent to which young students can make promisingness judgments (Bereiter, 2002; Bereiter & Scardamalia, 1993) and how educators could support them. By analyzing collaborative learning at multiple levels, this study examines promisingness judgments by 8- to 10-years-old students in their knowledge-building work on science across two consecutive years. The study addresses three central research questions: (a) to what extent could young students assess promisingness, defined as the knowledge-building potential of ideas, (b) how was the selection of promising ideas integrated with other discourse moves in knowledge building, such as proposing a theory and introducing evidence to

*Manuscript prepared for the 2013 AERA Annual Meeting in San Francisco, April 27 – May 1, 2013. Correspondence to: Bodong Chen; email: bodong.chen@utoronto.ca support a theory, and (c) how and to what extent did the selections of promising ideas facilitate idea improvement on both individual and group levels?

Promisingness Judgments in Knowledge Building

Like scientists in research laboratories (Dunbar, 1995), students engaged in knowledge building participate in constructive and progressive knowledge-building discourse. A knowledge building principle that frames such discourse is "collective cognitive responsibility" (Scardamalia, 2002), according to which students share responsibility for advancing their communal knowledge together. This collective effort calls for risk taking in pursuing novel solutions to problems, with an ongoing commitment to continual idea improvement. In this process, students make wide use of Knowledge Forum (KF, Scardamalia, 2004), a specially designed online, community space, to support their work.

Students in knowledge-building classrooms need to take initiative in analyzing problems and making plans to look for solutions. Throughout this process, they are often confronted with the significant challenge of identifying promising directions in order to avoid wasting time or becoming entrapped by unpromising ones. This challenge is shared by anyone working in creative contexts, in which neither single ideas nor simple combinations of them could constitute problem solutions. In these circumstances, substantial work is normally needed to develop ideas to address knowledge creation goals, and promising ideas provide indication of future success or good results in a specific problem domain.

As a matter of fact, identifying promising ideas and risks is a natural component of all kinds of creative processes. According to Howard Gardner (1994), promisingness figures intuitively when people detect "discrepent elements" in their work and guides people to "cast around" in order to achieve local coherence. This claim is supported by reported experience of creative individuals, like Nobel laureates. For example, when discussing the development of the theory of *relativity*, Albert Einstein, Nobel laureate in physics, 1921, said, "During all those years there was the feeling of direction, of going straight toward something concrete. It is, of course, very hard to express that feeling in words; but it was decidedly the case, and clearly to be distinguished from later considerations about the rational form of the solution (M. Wertheimer & Wertheimer, 1959, p. 228)." Similarly, at the *Science and Man* roundtable after the 1985 Nobel Prize ceremony, Michael S. Brown, Nobel laureate in medicine, said, "I think, we almost felt at times that there was almost a hand guiding us. Because we would go from one step to the next, and somehow we would know which was the right way to go. And I really can't tell how we knew that, how we knew that it was necessary to move ahead." Although the moments of important breakthoughts are usually under the spotlight of regular accounts of creation and innovation, the act of identifying promising ideas plays an crucial role in the process of creation, and creative people are especially good at it. Thus, the ability to identify promising ideas—ideas that with development might grow to something of consequence—is essential for creative work with ideas at all levels.

As educational researchers, a critical question we wish to tackle is how to help young students develop this kind of knowledge. According to Bereiter (2002), knowledge of promisingness is acquired over time as people engage in creative practices, by taking risks and learning from the successes and failures that are integral to the creative process. This type of knowledge increases with creative expertise and helps people improve their ability to take successful risks in the future. Thus, to prepare young generations to be future creative achievers in various fields, we should encourage them to make promisingness judgments in their day-to-day work and to learn from the results.

Methods and Data Sources

To support promisingness judgments in classrooms, a "Promising Ideas tool" was first implemented and integrated with Knowledge Forum (Chen, Chuy, Resendes, & Scardamalia, 2010). To tackle difficulties in grasping the concept of promisingness that were found in the first pilot study (Chen, Chuy, Resendes, Scardamalia, & Bereiter, 2011), a pedagogical intervention was designed and integrated into the second pilot study with Grade 3 students when they were studying "soil." With the Promising Ideas tool, students were engaged in two iterations of promisingness evaluation of their community ideas, with a goal to define next steps. They tagged promising ideas in Knowledge Forum and collectively exported them to new views for further inquiry. Initial analysis of data suggested that students as young as 8 years of age can make promisingness judgments that facilitate knowledge advancement in their work (Chen, Scardamalia, Resendes, Chuy, & Bereiter, 2012).

In this study, we kept working with the same class of students after they entered Grade 4. Most students maintained in the same class, with a size of 21, taught by a different teacher. In studying a "habitats" unit, students participated in a similar intervention as in Grade 3, tagging promising ideas in their communal space. In a later unit about "light," no intervention was planned and students were on their own to independently evaluate promisingness. To get a sharpened understanding of the dynamics of promisingness judgments by this class, we analyzed data from two consecutive years at multiple levels. An overview of dataset is described in Table 1.

Table 1: *An Overview of Dataset*

Grades	Views	Notes	Ideas
Grade 3	Grade 3 Soil 2010/11	39	57
	Where does soil come from?	87	94
	Worms and Soil	37	0
Grade 4	Grade 4 Habitats 2011-12	129	37
	Grade Four Light 2011/12	113	11

Data analysis first focused on the individual level. Relationships between promisingness judgments by each student and a number of important knowledge building measures were investigated. These measures included *counts of individual note-reading and note-writing actions*, *ways of contributing measures* (Chuy, Zhang, Resendes, Scardamalia, & Bereiter, 2011) and *scientficness* scores (Zhang, Scardamalia, Lamon, Messina, & Reeve, 2007). Numbers of individual reading and writing activites were directly exported from Knowledge Forum. To analyze ways of contributing measures and scientificness scores, content analysis (Chi, 1997) was conducted on notes written by each individual student. Firstly, we coded each note according to the *ways of contributing scheme* that categorizes the ways students contribute to knowledge-building discourse; it is composed of six main contribution categories, including posing a question, theorizing, introducing evidence, working with evidence, making analogy and synthesizing, and supporing discussion, and 24 sub-categories (see Chuy et al., 2011). Based on coding results, we further measured each student's (a) *contribution diversity*—the diversity of one's contribution repertoire represented by the numbers of main- and sub-categories one covered, and (b) *contribution richness*—average number of contributions contained in each note written by one student. Secondly, to gauge the level of understanding of each student, we also coded notes using a four-point *scientificness* scheme (Zhang et al., 2007), which includes: 1—pre-scientific (containing a misconception while applying a naive conceptual framework), 2—hybrid (containing misconceptions that have incorporated scientific information), 3—basically scientific (containing ideas based on a scientific framework, but not precise), or 4—scientific (containing explanations that are consistent with scientific knowledge). Mean of scientificness scores of notes was computed for each students to represent one's scientific understanding of relevant subject matter.

To interpret results of quantitative analysis and to uncover micro-level dynamics of promisingness judgments, temporal analysis of individual Knowledge Forum activities was conducted. For each student, we sorted their note reading, writing, and idea tagging activities in chronological order and mined relationships among these events. A number of patterns of promisingness evaluation were identified and will be discussed below.

At the group level, we focused on conceptual progress collectively achieved by groups of students. In knowledge building, student collaboration was mostly emergent, with contributions naturally aggregating around a few key problems emerging in this community. To study the extent to which promisingness judgments have influenced conceptual progress in each theme, we first identified conceptual lines of inquiry in the Knowledge Forum views of students' two years of work; they were called "idea threads" (see Zhang, Scardamalia, Reeve, & Messina, 2009). Identified idea threads were further evaluated in terms of progress they have made, and were sorted into two categories: (a) threads with substantial advancement, and (b) threads without clear progress for an extended period of time. We then compared presence and dynamics of promisingness judgments in each type of threads, to inspect possible impact of promisingness jugments on knowledge advancement. Student notes and picked promising ideas, as well as their timestamps, were tracked to analyze group progress and interaction between promisingness judgments and other discourse moves. Examples of "successful" and "improvable" idea threads will be presented below.

On the community level, Social Network Analysis (Scott, 1988; Wolfe, 1997) of reading, building-on and idea tagging interactions was conducted, to get a bird view of the synergy of these activities and to uncover impact of promisingness judgments on social dynamics of knowledge building. Characteristics of these networks were compared across different discourse phases in the class. Global level SNA measures, such as density and average path length, were used to evaluate connectedness of these networks. Apart from the community level, we were also interested in phenomena on the local and micro levels in these social networks. Modularity detection was applied to identify possible subgroups and cliques in each network. Moreover, each student's positions were compared across different types of network, based on individual-based SNA centrality measures for each student. With these measures on multiple levels, we could inspect possible impact of promisingness judgments on social dynamics of knowledge building.

Results and Discussion

For individual students, how was promisingness evaluation correlated to knowledge building measures?

As promisingness evaluation is an integral component in knowledge-building discourse, it is of interest to study its relations with other knowledge building activities. First of all, results of correlation analysis indicated that the amount of promising ideas tagged by a student was significantly correlated with number of notes written (r = .62, $p < .01$) and number of notes read by the student (r = .53, $p < .05$). These results indicated that the more active a student read or write notes on Knowledge Forum, the more promisingness judgments she is likely to practice. However, since results also showed a significant correlation between number of written notes and number of notes read (r = .65, $p < .01$), no causal relationship could be concluded. It was not clear which activity—reading, writing, or idea tagging—could be the cause, or whether all these three types of activities were driven by a fourth factor. Further interpretation of these correlations relied on content analysis on knowledge-building discourse.

Second, promisingness judgments were found not significantly correlated with ways of contribution measures, including total number of contributions (r = .34, *n.s.*), contribution diversity on main categories (r = .03, *n.s.*) or sub-categories (r = .18, *n.s.*), or contribution richness per note (r = -.03, *n.s.*). These results were not surprising because students from Grade 3 and 4 did not show a rich repertoire of ways of contribution in their work. For example, average contribution richness of Grade 3 students was pretty low (M = 1.34, SD = .40), implying that students could only make about one type of contribution in each note they wrote. Also, on twenty four different ways of contributing subcategories, each student could only make around four types of contributions (M = 4.32, SD = 2.38), most of which were in the *theorizing* main category. Therefore, ways of contributing mastered by this group of students were overall limited. In this case, it is understandable the correlations between promisingness judgments and ways of contributing measures were non-significant and promisingness judgments did not lead to richer ways of contributing by students in this class.

Lastly, promisingness judgments were not significantly correlated with scientificness score either (r = -.30, *n.s.*). This finding seemed to contradict with our previous finding that scientificness scores increased across three discourse phases in the Grade 3 class (Chen et al., 2012). However, as further analysis showed, the number of notes contributed by each individual, as well as their quality, varied a lot within each view. Students who were active in contributing ideas also posted a number of misconceptions or pre-scientific ideas along with scientific ones; at the same time, some students who only contributed one or two notes in a view might get a higher average scientificness score because they did not post their naive conceptions at early stages of the discourse. Thus, average scientificness score of a student in each view might not well reflect one's individual conceptual understanding, and insights from qualitative analysis were needed.

How did promisingness judgments influence individual activities in knowledge building?

To get a deeper understanding of how promisingness judgments affected knowledge-building activities on the individual level, we analyzed qualitative data from each student's note writing and promising idea tagging. Notes and tagged ideas were sorted in chronological order, and a temporal analysis (Hannan & Tuma, 1979; Mercer, 2008) was conducted for each student's profile. Analysis identified the following themes of promisingness judgments by Grade 3 and 4 students.

1. **Ideas tagged by students as promising were usually relevant to**

ideas posted by themselves, and could result in knowledge revisions or integrations. Students usually brought along their own interests in idea tagging. As a result, most ideas highlighted by students were relevant to ideas posted by themselves. To investigate how the actions of tagging promising ideas affected one's knowledge building activities, we analyzed subsequent notes written by a student after she tag each promising idea. Firstly, results indicated identified ideas could urge students to rethink their ideas, and eventually lead to revisions of understanding. For example, S9 posted her first note about "how worms sense light": *"My theory is because we have a sense of up and down worms have a sense of light and dark."* A few days later, she identified a promising idea written by S6 that *"the worms feel heat and the light has heat and dark dosen't!"* In the next note she wrote, *"My theory is that it also has something to do with heat. Like when you walk into the dark it gets colder because there's less sunlight... They don't need eyes because they can feel heat like us."* Apparently, she revised her original thought based on a simple analogy to a more sophiscated idea with more coherent reasoning. In some other cases, tagged ideas that complement or enrich one's own ideas could result in efforts of integrating them into more advanced explanations. For example, S13 firstly posted a note, *"My theory is that soil is made out of rocks that get turned into sand. then you maybe take a little bit of grounded up wood. You take a little water then a little sunshine and there is your soil!"* Then she picked an idea from S8, *"the soil is made from rocks it gets all broken up from the wind and getting rain or something watery on it."* In the next note she tried to integrate the picked idea into her original one: *"My theory is that soil is dirt, rocks, little bits of water and life. The rocks get smashed up. Then mix it with the dirt. Then add water to make it moist. the worms help the soil and the poop and the worms make air holes."* By engaging students in the intentional process of identifying promising ideas in the community, their attention could be raised to interconnected ideas that might otherwise get neglected. This process of grappling with multiple perspectives and reformulating increasingly interconnected views about scientific concepts serves as building blocks of symmetry knowledge advancement (Scardamalia, 2002), knowledge integration (Linn, Lee, Tinker, Husic, & Chiu, 2006), and conceptual change (Vosniadou, 1994) in science learning.

2. **The intentional effort of tagging promising ideas brought students' attention to new, emergent topics and lead them to participate, but the ways of participation varied**. In addition to the analysis of the impact on personal understanding, we also analyzed the extent to which promisingness judgments affected participation in group collaboration. Results showed various types of participation after a promising idea is tagged. In some cases students participated by simply agreeing upon or repeating a tagged idea. On other occasions, students could contribute insightful ideas and substantially improve their group's shared

understanding. For example, S2 had not posted any note before highlighting an idea about "worms": *"the worms feel heat and the light has heat and dark dosen't."* A few days later, he posted a note with an alternative explanation, *"My theory is that worms don't have eyes they can sense the difference between soil and the outside world. Because they can feel the difference in humidity."* One week later, he further developed his idea and came up with a scientific explanation, *"worms don't have eyes they have photo-receptors which catch the light and if they go outside too long the photo-receptors will shoot off and the worms will get paralyzed. . . "* These new contributions led a few other students to grapple around the scientific concept of "photoreceptor" and helped boost knowledge advancement of the whole group.

3. **While promisingness judgments could lead to participation and idea improvement, it was common that students failed to act upon identified promising ideas**. As results indicated, some students tagged a number of ideas but did not build on or make reference to any tagged ideas. On the other hand, students might identify ideas that seemed to be interesting but actually irrelevant to their own ideas. In this case, students tagged ideas without the intention to further develop them. For example, S20 was the most active student in identifying promising ideas in this intervention. She identified 35 ideas in two sessions of promisingness judgments. However, a lot of ideas she highlighted were controdicting with each other that almost represented all key explanations proposed in the class. Moreover, she did not make any effort to sort or integrate different explanations to achieve any explanatory coherence. A similar situation happened with S8, who highlighted a number of ideas about "where does soil come from," but did not post any note related to that question. Thus, while in many cases students could work creatively with identified promising ideas, they may need additional scaffolding in this area.

4. **Individual difference in the capability of making promisingness judgments was evident**. Some students had a fairly good sense of promisingness, tagging ideas leading to promising and fruitful directions as shown in subsequent discussions. For example, a number of students, such as S9, S16, S17 and S19, showed a strong sense of promising directions in their discourse. Most ideas they picked could represent the cutting-edge issues in the class, and as shown in examples above, some of those identified ideas got further developed and lead to conceptual breakthroughs for the whole class. On the other side, however, some students identified simple facts or already heavily discussed questions as promising. For example, S7 and S8 picked the leading question posted by the teacher even if it had been discussed by the whole class for a long time. S5 and S11 identified a few simple facts as promising ideas, such as *"some reptiles live in wet places"*, which did not lead to any conceptual breakthrough in their discourse. Moreover, students also differed on number of attempts in

making promisnigness judgments (M = 9.73, SD = 8.71). Furthermroe, it also should be noted that some students gradually developed a habit of promisingness judgments in knowledge building. For example, a few students became active users of a newly designed scaffold—"A promising idea"—in writing their own notes, and a few students spontaneously used the tool to tag promising ideas in later grades without any prompt from the teacher. Overall, students' capability in making promisingness judgments varied, and further research is needed to find out which factors, such as content knowledge and epistemic skills, have led to this difference.

5. **Regardless of varied capability in evaluating promisingness, it should be noted that some students gradually developed a habit of promisingness judgments in knowledge building**. When studying the light unit in Grade 4, a few students spontaneously used the tool to tag promising ideas without any prompt from the teacher. Also, a few students became active users of a newly designed scaffold, i.e., "A promising idea is" in writing their own notes. Moreover, some students tried to signal promisingness in their notes by tagging "promising" ideas in them.

How did promisingness judgments influence group dynamics in knowledge building?

To investigate the extent to which promisingness judgments could boost conceptual breakthroughs in a group, further analysis focused on "idea threads," which were defined as conceptual lines of inquiry in knowledge-building discourse (see, Zhang et al., 2007). Two representative threads are presented below. The first thread from the light unit illustrates a limited presence of promisingness judgments and failure of utilizing it to advance discourse. As shown in Figure 1, this thread was initiated from the question of "why light will not pass through solid objects like a wall." A few students quickly came up with a few possible explanations, which contained typical misconceptions. After that, the whole group was entrapped by these misconceptions and made little progress for quite a while. Later S16 posed a critical question that confronted the widely accepted misconceptions, but unfortunately this thread ended at that point. In this process, only S14 were tagging ideas; she identified note # 33 which could potentially alter the discussion focus from "density" to "transparency." However, she did not deeply participate into the discussion and that idea got neglected.

The second thread which focused on "whether worms have eyes" was from the "Worms and Soil" view in the soil unit. This thread originated from a previous view named "Where does soil come from", in which worms emerged to be a heated topic. In that view, students collectively identified a list of promising ideas and picked the top three to export to this new view. As illustrated in Figure 2, a number of students were active tagging promising ideas and bringing in thoughts from other threads. From the explanation of temperature guided sense to photoreceptors, it was evident that some students

- #20 S9: {[I need to understand]: why will the light not go through the solid object. }
  - #23 S10: {[My theory]: it is the solid object is solid and it is not seen through. }
  - #31 S13: {[My theory]: is that maybe it does but you just don't see because its a solid object. }
  - #35 S2: {[My theory]: is that light is not strong enough.}
  - #42 S3: {[My theory]: is that it bounces off the thing and rebounds off everything. }
  - #52 S19: I don't think so. Because I think that the wall is solid so the light wouldn't be strong enough to go through.
  - #41 S15: {[My theory]: is that light bounces off an object so it can't go through. }
    - #57 S4: {[My theory]: is that the light only sometimes bounces off the object }
  - #69 S19: "Cause the solid object is TOO solid and light bonces"
  - #28 S4: {[A promising idea]: is that the light won't go through cause the wall is too dense. }
    - #33 S10: {[My theory]: is that the dense wall is not seen through and the reason light travels through, for example a plastic container, is that it can be seen through.}
    - #34 S9: "i agree with you because it is solid and very hard"
    - #37 S14: you're right that light won't go through the wall. But it will bounce off.
    - #30 S16: are you sure?
      - #39 S14: yes
        - #54 S16: "I know that S14. I just wanted to make sure that she actually knew that… and just to tell you I sorta wanted a response from S4!"
          - #73 S16: **what if it was a glass wall????**

Figure 1: Thread 1

have achieved considerable knowledge advancement. For example, S7 initially made the connection between temperature and light (note #1) and further defended this idea with three reasons (note #14); later she brought in the evidence that worms do not have eyes but sense light by photoreceptors (note #25) and further questioned where the photoreceptors should be located (note #36). Promisingness judgments—by a number of students in the group—have played an important role in this advancement from naive theories to scientific explanation, by identifying directions and engaging students in sustained discourse to improve their ideas.

In summary, collective promisingness judgments integrated with continuous efforts to further develop identified ideas could lead to substantial conceptual breakthroughs, while solo judgments or judgments without further commitment will not make much difference.

Social aspects of promisingness judgments in the knowledge community

Social Network Analysis (SNA) has been widely used in studying the patterns of student interaction in computer-supported collaborative learning (CSCL) and knowledge building (e.g., Chan & van Aalst, 2004; Laat, Lally, Lipponen, & Simons, 2007). Instead of studying individual behaviors, SNA focuses on describing patterns of interaction, uncovering their effect on individuals, and investigating the structure of the community. To study the social aspects of

- #2 T: *{[I need to understand]: how worms tell the difference between light and dark? Do they have eyes? }*
  - #1 S7: *I think that the worms feel heat and the light has heat and dark dose'nt!*
  - #11 S4 & S18: {[My theory]:} is that they feel the brightness of the moon and then since the moon is so bright they feel the light and then they know it's day time. (*Note: S18 tagged note #3 as well as note 75 from the previous view before posting the note.*)
  - #12 S3: {[My theory]: is that worms don't have eyes they can sense the diffrens betwen soil and the outside world. Becuase they can feel the difference in humidity } (*Note: S3 tagged note #1 in this view, as well as note #75 and #85 about six sense in the previous view before posting this note.*)
  - #3 S10 & S14: *{[My theory]: is because we have a sense of up and down worms have a sense of light and dark. Like when we have been in the dark for a long time when you come out even when your eyes are closed you can still feel the light. }*
    - #16 S10 & S14: {[My theory]: is that it also has something to do with heat. Like when you walk into the dark it gets colder because there's less sunlight, and when you're in light it's warmer because there's more sunlight. They don't need eyes because they can feel heat like us. Light and dark and warm and cold are kind of the same because light is warm and dark is cold.} (*Note: S10 tagged note #1 before posting the note.*)
  - #4 S19: {[My theory]: is that they have a sense of the light and dark. They feel heat in the light, and they feel coolness when they're in the dark. } (*Note: S19 tagged note #1 before posting the note.*)
    - #14 S7: "{[I need to understand]: if worms have eyes my theory is that they do'nt because 1. if they did the soil would get into their eyes unless their eyes had see-through membranes on them to stop that but that would be to complex for worms! The second reason is that worms are too primitive to have eyes. That's why I think that they have a special sense that tells the worms if it's light or dark through the heat, when it's light outside they feel heat and when it's dark it's cold. }"
      - #19 S13 & S19: {[The evidence shows that]: worms do not have eyes. they have photoreceptors in their skin! }
  - #15 S20: {[My theory]: is that worms have a fifth sense insted of vision. Platapi have a six sense insted of five senses like other living creatures. The worms six sense is electro charges. }
    - #17 S10 & S14: {[I need to understand]: what are electro charges? }
      - #20 S8: {[My theory]: is that they little eltrec charges }
        - #22 S21 & S2: {[My theory]: is that electro charges are the thing that send out electricity and they bounce off the object and go back }
  - #6 S21 & S2: {[My theory]: is that they are guided by heat } (*Note: S21 tagged note #3 before posting the note.*)
    - #13 S19 & S13: {[My theory]: is there skin senses that their skin senses the heat, and the cold. }
      - #25 S7 & S17: {[The evidence shows that]: worms don't have eyes because they have photoreceptors we have those in our eyes. Photoreceptors sense the light so the worms can move. The light patterns show the worms where to go! Heat is in the light and the photoreceptors also help them to sense heat. }
  - #34 S3: worms don't have eyes they have photorecers which catch the light and if they go out side to loug the pohorecepters will shot off and the worms will get parylzed . the worms will not mind red light but hate blue and white light
  - #36 S7: {[My theory]: is they might be able to do that with their skin? }

Figure 2: Thread 2

promisingness evaluation and its impact on other knowledge building activities, SNA was conducted on three types of interaction in this class—*note reading*, *building on*, and *promising idea picking*. For each grade, we partitioned data according to different discourse phases (in Grade 3) and different units (in Grade 4). For each type of interaction, related Knowledge Forum log data were exported, analyzed, and then represented as a network, in which students in the class were represented as nodes and interaction among them was denoted as links connecting nodes. The same SNA procedure was applied on each type of interaction data during different periods of time in both grades. In this analysis, we investigated patterns of social networks at different levels—from global to local to individual—in order to understand dynamics of promisingness judgments from different angles.

Global level analysis of networks To obtain a general understanding of each network, we focus on a few important measures of social networks. Haythornthwaite (1996) highlights five principles used by network analysts to examine a social network; they are: *cohesion*, *structural equivalence*, *prominence*, *range*, and *brokerage*. At the global level, we focused on *cohesion*, which refers to the extent to which individual students directly interact with each other in the community. The concept of *network density* is closely related to the democratization of knowledge and symmetric knowledge advancement, two important principles of knowledge building (Scardamalia, 2002). Related to density, the measure of *average weighted degree* denotes the average weight of connections in the network. It could also be used to represent how cohesive a network is. Another important measure to characterize the connectedness of a network is the *average path length* (Abraham, Hassanien, & Snášel, 2009). The average path length denotes the average number of steps along the shortest paths for all possible pairs of nodes, while the diameter of a network measures the longest shortest path between pairs of nodes within this network. Table 2 summarizes results of analysis related to these measures.

Table 2: *Measures of social networks*

Grades	Interaction	Phases	Nodes	Edges	Density	APL	AWD
Grade 3	Reading	Phase I	19	136	40%	1.26	61.16
		II	19	165	48%	1.37	65.58
		III	19	145	42%	1.36	45.37
	Building on	Phase I	19	33	10%	1.26	61.16
		II	19	53	15%	2.37	7.16
		III	19	19	6%	1.92	2.10
	Idea picking	Phase I	19	61	14%	1.71	6.71
		II	19	57	14%	1.86	9.14
Grade 4	Reading	Habitats	21	306	73%	1.24	138.48
		Light	21	299	71%	1.25	96.10
	Building on	Habitats	21	47	12%	2.64	7.33
		Light	21	36	8%	1.73	4.48
	Idea picking	Habitats	21	31	7%	2.97	3.43
		Light	21	8	2%	1.33	1.05

Overall, the number of edges, density and average weighted degree of note-reading networks are much higher than building-on and idea-tagging networks. The density scores of note-reading networks in three units were respectively 69%, 73% and 71%; students in both grades were quite active reading each other's notes. However, the density of building-on and idea-picking networks was much lower. By comparing results from two grades, the density and average weighted degree of two types of networks were much higher in the soil unit of Grade 3 (26%, 13.16; and 26%, 16.70) than two units in Grade 4. Similar patterns can be found on the diameter and average path length measures. By further comparing different phases in the soil unit, we found the density and average weighted degree of idea-picking networks has maintained at a same level in the first two phases, and those measures of building-on networks was improved, from 10%, 3.9 to 15%, 7.16. Those measures was not very high in Phase III, possibly because the student have only worked in this phase for only one week, from June 6 to 13, while have spent two weeks in the other two phases. Given time, they might have got more chances to build on each other.

In order to investigate the relationships between networks of different types of interaction, correlation analysis was conducted over the density measure. Results indicated the density of idea-picking network was significantly correlated with the density of building-on networks (r = .84, p < .05), but not with that of note-reading network (r = -.02, *n.s.*). Densities of reading and building-on networks were not significantly correlated either (r = .46, *n.s.*). Thus, it is possible that the collective effort of judging promisingness could promote richer collaborations among students.

Focusing on the idea-picking networks, in phases with interventions, i.e., Phase I and II in Grade 3 and the habitats unit in Grade 4, the density and average weighted degree were much higher. In Phase III of the Grade 3 soil unit and the Grade 4 light unit, promisingness judgments by students were spontaneous, and only a few connections were made. Therefore, for students as young as 8- to 10-years-old, intervention seems to be necessary to engage them in productive promisingness judgments.

Sub-communities and cliques On the local level, modularity detection was conducted on each network to uncover possible sub-communities and cliques. Social networks were also visualized to study the structure of subgroups. In the note-reading networks in both grades, results did not identify any sub-community; most students were actively reading all notes in the community. In the building-on and idea-picking networks, however, sub-communities centered on some prominent students could be found. In these social network visualizations (See Figure 3), the size of a node denotes its indegree. For example, in the building-on network, the size of a student's node means how many times her notes was built on in the class. The width of a line represents the weight of that link. In the building-on network of Phase I in Grade 3, three sub-communities emerged, but no clique was found. Four students were isolated in the graph, which means they did not build on other students' ideas or get built on by others. Also, the links between a few pairs of students were much stronger than other links; this implies a strong collaboration between these pairs. The idea-picking networks of the same phase was more cohesive, with only one big community and three isolated students; links were also more balanced. In promisingness judgments, a student could identify many ideas from other students that they had not intensively worked on. The process of evaluating promisingness of ideas in the whole community might help break boundaries between subgroups and encourage the emergence of more collaboration. Analysis on the building-on and idea-picking in Phase II showed favorable proof of this. In Phase II, the building-on network was made up of two sub-communities and one isolated student (see Figure 3); links between students also became more balanced and the density of connections also increased (as discussed in the previous subsection). There were also denser linkages in the idea-picking network.

Previous sections discussed the lack of commitment to identified promising ideas. Related to that, we compared the idea-picking and building-on networks within a phase and across two consecutive phases. Analysis on network structure showed pervasive discrepancies between two types of networks, on both degrees of nodes and distribution and weights of links. For example, student 12 and 15 built on each other a lot in Phase I of the soil unit, but they were not even connected in the idea tagging network in the same phase; in Phase II, they kept building

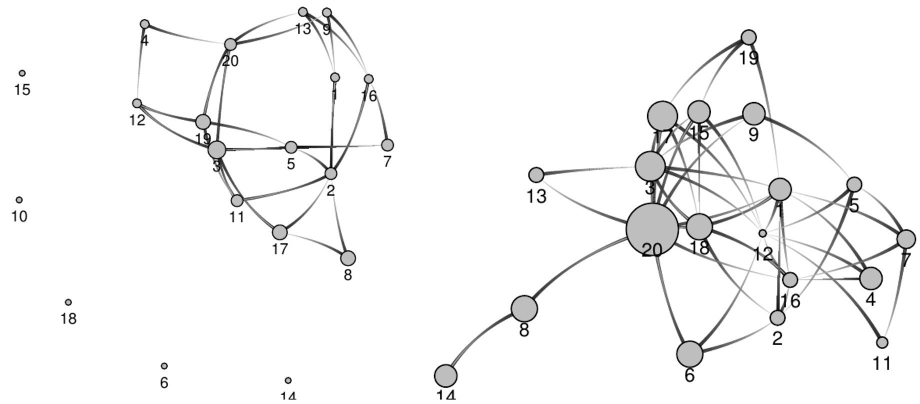

Figure 3: Building-on networks in Phase I and II of Grade 3

on each other but did not tag any of the other's ideas as promising either. On the other hand, student 5, who was the most active promisingness evaluator in Phase I, identified a number of ideas contributed by student 18 as promising; however, they were not directly interacting with each other in Phase II. A similar story can be told of student 9 and 13; student 9 picked a number of student 13's ideas as promising in Phase I, but he was not connected at all in the next phase's building-on network. These contrasts seemed to agree with our analysis in previous sections that some students did not take actions on identified ideas to further improve them.

Analysis of individual students in social networks On the individual level, we focused on the aspects of *prominence* and *brokerage*. Among many different measures, *betweenness centrality*, defined as the extent to which an actor sits between others in the network, represents the importance of a student in the whole network. It quantifies the control of a human on the communication between other humans in a social network (Freeman, 1977). In knowledge building activities, the measure of betweenness centrality could stand for the influence on idea linking in the community.

To study how a student's position in idea tagging activity related to her performance in other activities, we conducted correlation analysis of students' betweenness centrality scores between the idea-picking and reading and building-on networks. Results indicated that betweenness centrality in idea tagging was significantly correlated with that measure in reading ($r = .48$, $p < .05$) and building-on networks ($r = .52$, $p < .05$). Not surprisingly, this measure was also significantly correlated with the number of identified ideas ($r = .76$, $p < .001$) and notes contributed by the student ($r = .47$, $p < .05$). In order to investigate the relation between a student's position in promisingness judgments and her knowledge achievement, we also correlated the betweenness centrality score with the scientificness score. However, results did not confirm a significant correlation between them (r = -.26, *n.s.*). Thus, how influential a student is within the idea-picking network was related to her position in reading and building on activities. The efforts of tagging ideas by different students were related to efforts of building on other students' ideas at a macro level, although previous analysis on student discourse partially negated this link at the individual and group levels.

By visually analyzing different social networks, we found students' positions varied in different types of interactions and across different discourse phases as well. A student who held a central position in the idea-picking position might not necessarily be prominent in the building-on network. However, we did find some students who consistently maintained quite central positions across different networks. For instance, student 4, 12, and 20 were quite active and central in building-on and idea-tagging networks across three phases in Grade 3. Their indegrees and outdegrees were comparatively high and their scores in betweenness centrality was also on the top of the list.

Analysis also identified students who were actively doing one activity but not active in doing another. For example, student 21 was active in tagging ideas in all three phases in Grade 3 but did not actively built on other students' ideas. A student's contribution was usually not consistent across different phases, and their collaboration was quite opportunistic. Also, it should be noted that the relationship between building on and being built on, as well as tagging and being tagged, was not symmetric. For example, student 22's outdegree in the idea-tagging network, i.e., the frequency of picking promising ideas, was consistently among the top three across three phases in Grade 3; however, his ideas were not often identified as promising by other students. In building-on networks, student 5's notes were frequently built upon by other students, but he was not very actively in building on other students' ideas. As can be visually interpreted, individual difference in ways of connecting in different types of networks was obvious and quite complex. Whether promisingness judgments could promote richer and more fruitful connections in a knowledge community is open to future research.

In summary, the social network analysis on knowledge-building activities in the class identified a possible effect of promisingness judgments in promoting connection between students and ideas. As indicated in the global-level analysis, density of the building-on network increased across phases of promisingness intervention. At the local level, sub-communities became more connected across different phases. Meanwhile, we also found most young students might need continuous guidance in promisingness judgments although previous analysis found a few students had developed the habit of judging promisingness.

Significance

Promisingness judgments are thought to be the heart of effective, creative action, and improved by immersion in progressive problem solving (Bereiter & Scardamalia, 1993). Faced with ill-defined problems, knowledge creators usually need to make choice involves risk and uncertainty, and the capability of identifying promising directions becomes crucial in the absence of known or well-traveled basis for action. In contrast, school work is typically defined by well-defined problems of relatively short duration with fixed goals and continuous, clear feedback. Accordingly students usually have little chance to make "promisingness judgments" and dealing with plateaus in work, uncertainty and risk-taking which are required to work with ill-defined problems over extended period of time. This study represents the first effort to engage students in developing the capability of evaluating promisingness, to meet 21st century needs of knowledge creation and achieve 21st century potentialities.

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