# Promisingness Judgments by Grade 3 and 4

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Abstract

The ability to identify promising ideas is an important but obscure and undeveloped aspect of knowledge building. This study examines the dynamics of promisingness judgments in knowledge-building discourse by young students. Toward 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. Social network analysis found that promisingness judgments may help students linking ideas in their community but most students would need continuous support from tools or teachers. These results will inform the design of future classroom innovations to support promisingness evaluation by young students.

*Keywords:* promisingness, knowledge building, discourse, design-based research

## Introduction

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 the knowledge of their community. To advance community knowledge, knowledge building calls for risk taking in pursuing novel solutions to problems, with a commitment to continual idea improvement. In this process, students make wide use of Knowledge Forum (Scardamalia, 2004), an specially designed online, community space, to support their work.

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Students in knowledge-building classrooms need to take initiative to analyze problems and make plans to look for solutions. In this process, they are usually confronted with the significant challenge of identifying promising directions in order to avoid wasting time or becoming entrapped by unpromising ones (Bereiter & Scardamalia, 1993). This challenge is shared by anyone working in knowledge-creating 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 identifying promising ideas is an important step to decide how resources should be allocated. As a matter of fact, evaluation of promisingness and risk is a natural component of scientific reasoning in real-world laboratories (Dunbar, 1995). Promising ideas provide indication of future success or good results in a specific problem domain. Promisingness judgments guide action of the moment as well as overall approach. Thus, the ability to identify *promising ideas*—ideas that with development might grow to something of consequence—is essential for creative work with ideas, and knowledge of promisingness is crucial in every kind of creative work at all levels.

As educational researchers, a critical question we wish to tackle is how to help young students develop the capability of identifying promising ideas. According to Bereiter (2002), experts make use of their knowledge of promisingness, a type of *impressionistic knowledge*, to make successful promisingness judgments. The 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, helping 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 knowledge building work and to learn from the results.

This paper reports early efforts in a program of research that seeks to explore the extent to which young students can make *promisingness judgments* and how educators could support them. By analyzing collaborative learning at multiple levels, this study examines promisingness judgments by a class of students in their knowledge-building work across two consecutive years from Grade 3 to 4. The study aims to address three central research questions: (a) to what extent could young students assess promisingness, or the knowledge building potential of their own 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 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?

## Method

### Participants and Design

To support promisingness judgments in classrooms, a "Promising Ideas tool" was first implemented and integrated into Knowledge Forum (Chen, Chuy, Resendes, & Scardamalia, 2010). It includes three components: (a) a "highlight" feature that allows students to tag an idea within a note using a customizable categorization scheme, (b) a component aggregates all selected ideas within a same view, merges overlapping ideas, and visualizes them in a list,

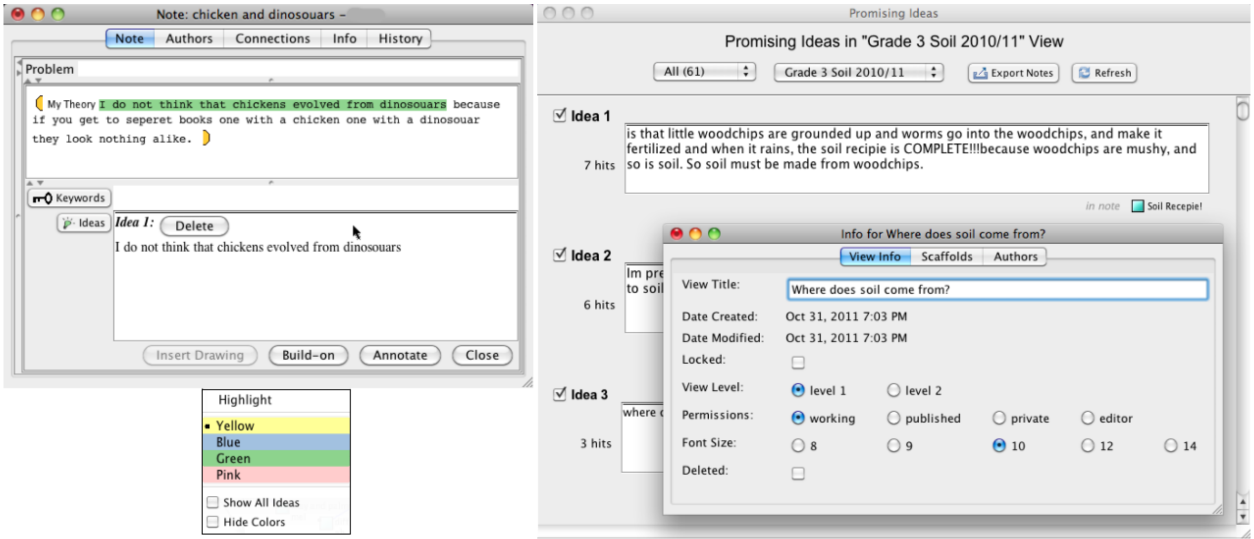


*Figure 1*. The Promising Ideas tool currently has three components: (a) tag an idea—on the left, a student can identify an idea with a customizable scheme; (b) list tagged ideas—in the background window on the right side, all identified promising ideas from a view are listed; and (c) export selected ideas to a new view—users can then select a subset of ideas from this list and export them to a new view (the foreground window on the right).

and (c) an exporting feature that allows students and teachers to export a subset of identified promising ideas from the list to a new view for further inquiry (see Figure 1). The third component brings life to the endeavor of identifying promising ideas more meaningful, by engaging students in identifying promising ideas with a commitment to define new directions for their work.

To tackle students' difficulties in grasping the concept of promisingness as shown 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 a science unit about "soil." In this pedagogical intervention, a teacher engaged students in discussing the concept of promisingness and helped them advance different but plausible definitions of the concept with meaningful examples. After this pedagogical intervention, 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 of their inquiry. They tagged promising ideas in Knowledge Forum and collectively exported them to new views for further investigation. Initial analysis of data suggests that students as young as 8 years of age could make promisingness judgments that facilitate knowledge advancement in their work (Chen, Scardamalia, Resendes, Chuy, & Bereiter, 2012).

During the next year, 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 students, taught by a different teacher. In the middle of their study on a science unit about "habitats," they were again invited to participate in a promisingness intervention, one similar to what they did in Grade 3. This intervention first started with a recap of the concept of promisingness introduced in the pedagogical intervention one year ago. After that, students were directed to conduct promisingness judgments on their Knowledge Forum view, picking ideas they thought were promising using the Promising Ideas tool. Then the whole class reviewed picked ideas together and had a discussion on identified ideas. No ideas was exported to any new view and this intervention did not carry on for multiple iterations. Students kept working on the same view till the end of that unit. In a later science unit on "light," no intervention was planned and students were not overtly invited to conduct promisingness judgments. Students were on their own to independently evaluate promisingness. In doing this, we were expecting to investigate the extent to which students could retain the habit of evaluating promisingness in their knowledge building work after months of discrete interventions.

### Data Analysis

To get a sharpened understanding of the dynamics of promisingness judgments by this class, we analyzed data from two consecutive years at multiple levels. Data were mainly composed of notes and identified "promising ideas" from five Knowledge Forum views this class has been working on. An overview of the dataset is described in Table 1.

Table 1
*Sample basic table*

| | Data | | |
|---|---|---|---|
| Grade | Views | Notes | Ideas |
| Grade 3 | Grade 3 Soil 2010/11 | 38 | 57 |
| | Where does soil come from? | 47 | 94 |
| | Worms and Soil | 40 | 11 |
| 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 the frequency of promisingness judgments and a number of important knowledge building measures for individual students were investigated with correlation analysis. Inspected measures covered both descriptive contribution indices, such as *number of tagged ideas* and *number of notes read* or *written*, as well as measurements of individual contribution diversity and conceptual understanding. Descriptive indices were exported from Knowledge Forum log data, while scores on individual contribution diversity and conceptual understanding were assessed through content analysis (Krippendorff, 2004) on student' Knowledge Forum notes. To assess contribution diversity, each student's notes were coded with the *ways of contributing scheme*, which is made up of 6 main contribution categories and 24 subcategories (Chuy, Zhang, Resendes, Scardamalia, & Bereiter, 2011). Ways of contributing measures, such as *contribution diversity* and *contribution richness* (Chen & Resendes, 2012), which represent a student contribution repertoire in knowledge-building discourse, were then calculated. To assess a student's conceptual understanding on a topic, this student's notes were coded with a four-point *scientificness* scale developed by Zhang, Scardamalia, Lamon, Messina, and Reeve (2007). A student's average score on scientificness was computed for each view to represent individual understanding on that topic.

To triangulate with results of correlation analysis and to uncover the effect of promisingness judgments on individual learning, we closely analyzed individual profiles of note writing and idea tagging in each phase of knowledge-building discourse. All note-writing and idea-tagging events were sorted in chronological order and the relationships between them were mined. A number of patterns were identified.

To investigate the impact of promisingness judgments on knowledge advancement on the group level, a number of discussion threads with participation from groups of students were analyzed. Student notes and identified promising ideas, as well as their timestamps, were tracked. Group progress and interaction between promisingness judgments and other discourse moves were further analyzed. Two representative threads of discourse will be presented and discussed in the results section.

On the community level, Social Network Analysis (SNA, Scott, 1988; Wolfe, 1997) was conducted, uncovering patterns in three types of interactions, i.e., note reading, building-on and idea tagging, and investigating social structures forming based on them. SNA may help us investigate the impact of promisingness judgments on note reading and writing by providing a "bird view" of the synergy of these different activities. Characteristics of social networks emerged from different types of interactions in different discourse phases were investigated in both grades. A variety of global level SNA measures, such as density, network diameter and average path length, were used to study these networks. 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. Each student's positions or roles were compared across different types of network. For all three levels of analysis, changes of social networks were also inspected across different phases of discourse.

## 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. Promisingness judgments in this class did not lead to richer ways of contributing by students.

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, Scardamalia, et al., 2012). However, as our 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. Thus, average scientificness score of a student in each view might not well reflect one's individual conceptual understanding, and qualitative measures were needed.

**How did promisingness judgments influence individual activities in knowledge building?**

To get a deeper understanding of how promisingness judgments affected individual students, we analyzed individual profiles of 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 among grade 3 and 4 students.

**1. Ideas tagged by students as promising were usually relevant to ideas posted by themselves, but subsequent reactions varied.** As reflected by subsequent notes, identified ideas could urge students to rethink their ideas, and eventually lead to revisions of understanding. For example,

> Student 14 contributed her first note on May 2nd, *"My theory is that the soil is made from worms + rocks = soil."*
>
> On May 9th, she identified a promising idea—*"then when it rains it makes the dried mud mushy"*—in the promisingness intervention.
>
> Later on when she posted a new note about "what makes soil," she wrote, *"the soil is made from rocks. it gets all broken up from the wind and getting rain or something watery on it."*

Apparently, student 14's original idea about what makes soil was revised after the tagging of that idea. For another example,

> Student 21 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: *"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 changed her mind and thought feeling light was not a natural sense for worms, but something related to heat.

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,

> Student 21 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, *"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."*

**2. The intentional effort of tagging promising ideas brought students' attention to some emergent topics and lead them to participate, but the ways of participation also varied.** In some cases students participated by simply agreeing upon or repeating a tagged idea. For example,

> In the "light" unit, student 4 firstly tagged an idea, *"My theory is that the light won't go through cause the wall is too dense."*
>
> Later on she participated into this thread by posting a few new notes, e.g., *"... I think that the wall is solid so the light wouldn't be strong enough to go through."* and *"Cause the solid object is TOO solid and light bounce."*

On other occasions, students could contribute insightful ideas and substantially improve their group's shared understanding. For example,

> Student 18 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 out side too long the photo-receptors will shot off and the worms will get paralyzed..."*

**3. It was common that students failed to act upon identified promising ideas.** Some students tagged a number of ideas but did not build on or reference any tagged ideas. For example,

> In the "light" unit in Grade 4, "why do so many colors appear when light hits on CD" was a heated topic. Students came up with a number of explanations, but none of them was close to scientific.
>
> In this process, student 12 identified an idea, *"the reason the CD changes color is because the angle of the light"*, which was quite promising from the perspective of researchers. But unfortunately she did not further participate in any way.

The same thing happened in other units with a number of other students. On the other hand, students identified ideas that seemed to be interesting but actually irrelevant to their own and had difficulties in connecting with them. It seemed some students tagged ideas without the intention or resolution to further develop them. For example, student 4 was the most active student in identifying promising ideas in both grades. She identified 35 and 11 ideas respectively in Grade 3 and 4. However, a lot of ideas she highlighted were competing theories that almost represented all key explanations proposed in the class. Also, she did not make any effort to sort or integrate different explanations. A similar situation happened with student 9, who highlighted a number of ideas about "where does soil come from." But he did not post any note in that unit.

These issues presented to be a challenge for design of future interventions. How could we design better tools to help students keep track of identified promising ideas and make connections between with other ideas.

**4. Individual difference in the capability of 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 student 2, 3, 21 and 22, showed a strong sense of promising directions in their discourse. Most of ideas they picked could represent the cutting-edge issues in their community, and some of those identified ideas got further developed and lead to conceptual breakthroughs for the whole class. For example,

> In discussing the topic of habitats, student 3 highlighted a promising question, *"if one animal dies, why would all the other animals die"*, and a promising explanation, *"My theory is that if one of the animals dies it will mess up the whole food chain."* And that lead to a heated discussion about "food chain" in the whole class.

On the other hand, some students identified simple facts or already heavily discussed questions as promising. For example,

> Student 7 and 8 picked the leading question *"what is a habitat?"* posted by the teacher even if it had been discussed by the whole class for a long time.
>
> Student 4 and 12 identified a few facts as promising ideas, such as *"some reptiles live in web places"*, which did not lead to any conceptual breakthrough in their discourse.

As for frequency of promisingness judgments, a number of students, such as student 9 and 23, who did not actively post notes were usually not active in judging promisingness either. This phenomenon might imply a fourth variable that drove note reading, writing, and idea tagging activities as we discussed in the previous section.

**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?

Previous analysis on community knowledge identified significant improvement across three discourse phases separated by two iteration of promisingness judgments (Chen, Scardamalia, et al., 2012). To investigate how and the extent to which promisingness judgments could boost conceptual breakthroughs at the group level, further analysis focused on discussion threads. Two threads, which represent improvable and successful practices of promisingness evaluation, are presented below.

The first thread which lasted for three weeks in the light unit illustrates a limited presence of promisingness evaluation and failure of utilizing it to advance discourse. As shown in Figure 2, 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. A few days later, student 16 posed a critical question that confronted the widely accepted misconceptions, but unfortunately this thread ended at that point. In this process, only student 14 were tagging ideas; she identified note # 33 which could potentially alter the discussion focus from "density" to "transparency," which might possibly lead the discourse to a promising direction. 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 also lasted for three weeks. It originated from a previous view named "Where does soil come from", in which worms emerged to be a shared interest among students. In that view, students collectively identified a list of promising ideas and picked the top three and exported them to this new view. As illustrated in Figure 3, a number of students were active tagging promising ideas and bringing in thoughts from other threads. In this process, their explanation gradually evolved from "temperature guided sensing" to "photoreceptors." By following the ideas of individual students, it was evident that some students have achieved considerable knowledge advancement. For example, student 7 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.

By comparing these two threads, it is evident that collective promisingness judgments integrated with continuous efforts to further improve identified ideas could lead to substantial conceptual breakthroughs, while solo judgments or judgments without commitment or investment to those ideas will not make much difference. These results will inform future revisions of interventions to support promisingness evaluation by young students.

### 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; Nurmela, Lehtinen, & Palonen, 1999; Palonen & Hakkarainen, 2000; Sha & van Aalst, 2003). 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 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

- #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 2*. Thread 1

- #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 3*. Thread 2

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*. On 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* or the *network diameter* (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 presents results of analysis related to these measures.

Table 2
*Measures of social networks*

| | | | SNA Measures | | | | | |
|---|---|---|---|---|---|---|---|---|
| Grades | Interaction | Phases | Nodes | Edges | Diameter | A.P.L. | Density | A.W.D. |
| Grade 3 | Reading | Phase I | 19 | 136 | 2 | 1.26 | 40% | 61.16 |
| | | II | 19 | 165 | 3 | 1.37 | 48% | 65.58 |
| | | III | 19 | 145 | 3 | 1.36 | 42% | 45.37 |
| | | *Total* | 19 | 235 | 2 | 1.23 | 69% | 172.1 |
| | Building on | Phase I | 19 | 33 | 6 | 2.58 | 10% | 3.9 |
| | | II | 19 | 53 | 6 | 2.37 | 15% | 7.16 |
| | | III | 19 | 19 | 4 | 1.92 | 6% | 2.1 |
| | | *Total* | 19 | 90 | 4 | 1.84 | 26% | 13.16 |
| | Idea picking | Phase I | 21 | 61 | 3 | 1.71 | 14% | 6.71 |
| | | II | 21 | 57 | 5 | 1.86 | 14% | 9.14 |
| | | III | 21 | 8 | 2 | 1.11 | 2% | 0.86 |
| | | *Total* | 21 | 111 | 4 | 1.74 | 26% | 16.7 |
| Grade 4 | Reading | Habitats | 21 | 306 | 2 | 1.24 | 73% | 138.48 |
| | | Light | 21 | 299 | 2 | 1.25 | 71% | 96.1 |
| | Building on | Habitats | 21 | 47 | 6 | 2.64 | 12% | 7.33 |
| | | Light | 21 | 36 | 4 | 1.73 | 8% | 4.48 |
| | Idea picking | Habitats | 21 | 31 | 7 | 2.97 | 7% | 3.43 |
| | | Light | 21 | 8 | 2 | 1.33 | 2% | 1.05 |

*Note*: A.P.L. = Average Path Length; A.W.D = Average Weighted Degree.

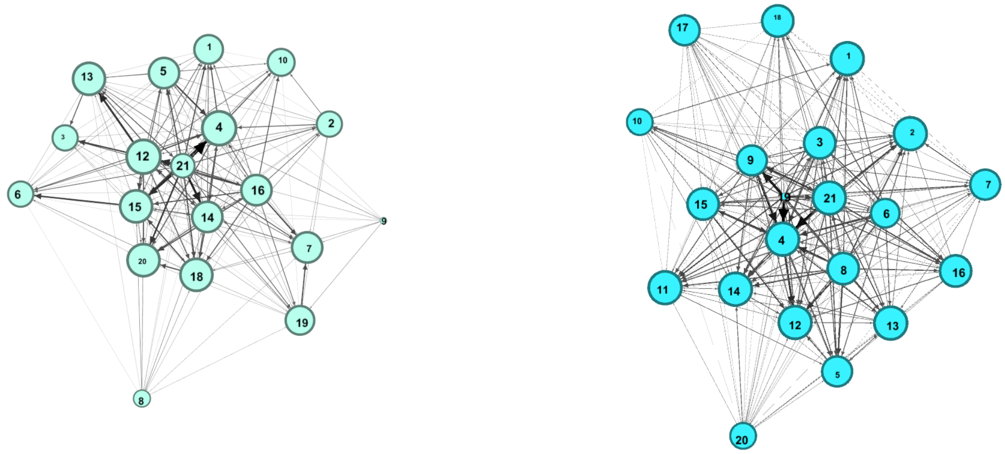
Overall, the number of edges, density and average weighted degree of note-reading networks are much higher than building-on and idea-tagging networks. The density scores of note-reading networks in three units were respectively 69%, 73% and 71%; students in both grades were quite active reading each 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, the density and average weighted degree of which were all below 10% and 10.00. 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. Using Gephi (Bastian, Heymann, & Jacomy, 2011), 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 (see Figure 4). In the building-on and idea-picking networks, however, sub-communities centered on some prominent students could be found (see Figure 5). In these social network visualizations, the size of a node denotes its indegree and the size of its label stands for its outdegree. For example, in the idea-picking network, the size of a student's node means how many times her notes was built on in the class and the size of her label implies her efforts to build on other students' ideas. 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 three pairs of students, i.e., student 4 and 13, 13 and 5, and 12 and 15, 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 (see graph (c) and (d) in Figure 5). In Phase II, the building-on network was made up of two sub-communities and one isolated student; 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;




(a) Grade 3 (b) Grade 4

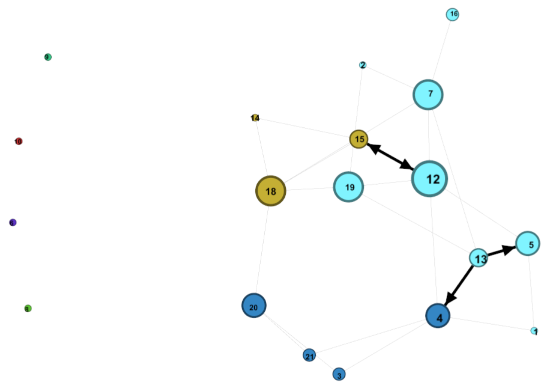
*Figure 4*. Note-reading networks in the Grade 3 and 4 classes

in Phase II, they kept building 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.

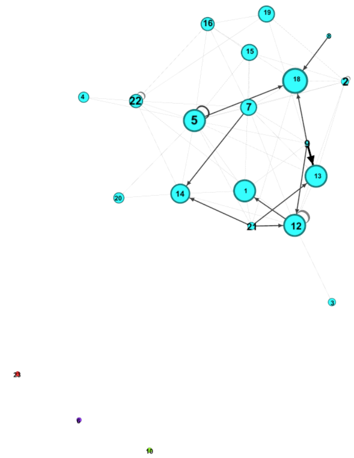
As for the prominent players in local communities, we found some students emerged to be connectors between subgroups. For example, student 4 maintained a central position since Phase II in grade 3 all through two units in grade 4 (see graph (e) and (f) in Figure 5). The next subsection will discuss more about individual students.

**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.

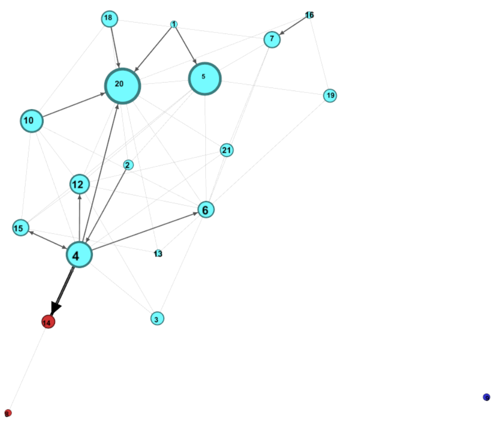
To study how a student's position in idea tagging activity related to her performance in other activities, we conducted correlation analysis of students' betweenness centrality scores between the idea-picking and reading and building-on networks. Results indicated that betweenness centrality in idea 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



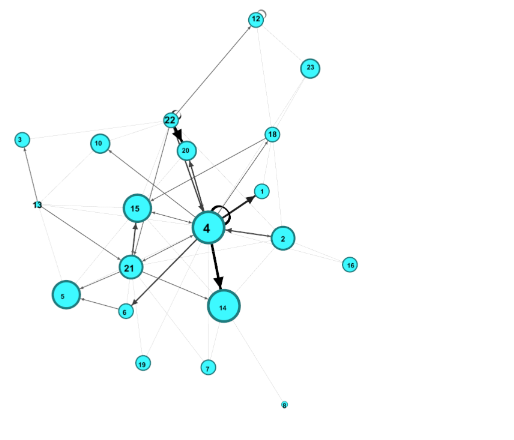
(a) Building-on network, Phase I in Grade 3



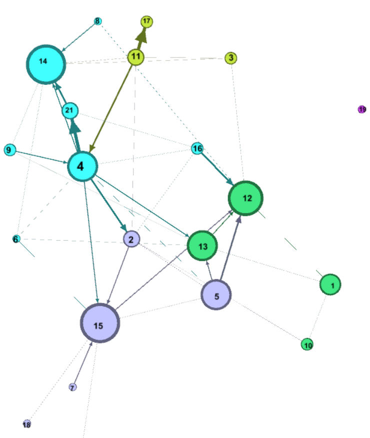
(b) Idea-tagging network, Phase I in Grade 3



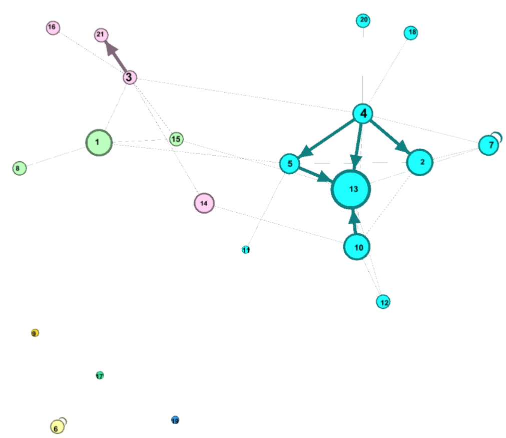
(c) Building-on network, Phase II in Grade 3



(d) Idea-tagging network, Phase II in Grade 3



(e) Building-on network, Habitats unit in Grade 4



(f) Idea-tagging network, Habitats unit in Grade 4

*Figure 5*. Building-on and idea-tagging networks in the Grade 3 and 4 classes

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, subcommunities 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.

## Conclusion

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 builds on a previous study that firstly attempts to engage a group of grade 3 students in doing promisingness judgments (Chen, Scardamalia, et al., 2012), by extending the intervention into grade 4 and further analyze data from student discourse. Prior analysis found knowledge advancement at the community level could be facilitated by promisingness judgments, based on assessment of scientificness of student ideas. This study extended the analysis to individual and group levels, looking for patterns in individual profiles and group dialogue of promisingness judgments. Varied types of promisingenss evaluation practice were found with individual students. Although students tended to pick ideas related to their own and could sometimes get involved in emerging topics, the ways they react differed from each other. More research and design efforts are need to find ways to better support students to keep track of and make connection between identified ideas. Meanwhile, it was delightful to find out some students had adopted the habit of promisingness judgment, keeping picking promising ideas in their database and using a "promisingness" scaffold even if the intervention was faded.

Analysis on group dialogue found both improvable and successful use of promisingness to boost group knowledge advancement. By comparing two representative threads of discourse, we argue that collective promisingness judgments integrated with continuous efforts to further improve identified ideas could lead to substantial conceptual breakthroughs, while solo judgments or judgments without commitment or investment to those ideas will not make much difference. Social network analysis further confirmed the possible connection between promisingness judgments and linkage of ideas, highlighting the correlation and impact of promisingness judgments on density of connections between students and linking ideas from sub-communities.

Future research will pursue improved way of facilitating promisnigness judgments of students at different grade levels. Following a design-based research approach (Collins, Joseph, & Bielaczyc, 2004), the Promising Ideas tool, as well as pedagogical interventions around it, will be further revised and tested in classrooms. Results from this study will guide our design of tools to keep students more engaged and informed in the process of knowledge-building discourse. At the same time, a developmental study that aims to uncover developmental patterns with promisingness judgments is planned. We believe by improving younger generation's capability of making promisingness judgments from an early age, we will get a better chance to meet 21st century needs of knowledge creation and achieve 21st century potentialities.

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