Knowledge Building Measures that Matter

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Abstract

This paper reports a secondary analysis that examines the relationships between a set of socio-behavioral, content, and lexical measures of knowledge building discourse and student scientific understanding. These measures were applied to an optical Knowledge Forum database created by 22 fourth-graders over four months. The results validated a number of measures characterizing productive knowledge building that can lead to deep understanding. These measures point to active contribution to the community knowledge space, awareness of contributions, idea-centered progressive discourse, and collaborative and distributed engagements.

Knowledge building—the creation of knowledge as a social product—is a pervasive phenomenon in a knowledge-based society. Schools of today need to incorporate knowledge building processes into student learning. Knowledge building moves away from the traditional learning contexts in a number of important ways: from individual to collaborative processes and outcomes; from pre-designed to emergent goals; from content coverage to depth of understanding; from standard content to diverse expertise (Scardamalia, 2002; Scardamalia & Bereiter, 2006; Zhang, Scardamalia, Lamon, Messina, & Reeve, 2007). Traditional research and assessment tools (e.g., standard test, thinking-aloud) generally measure individual learning processes and outcomes based on predefined learning objectives and curriculum standards. Although these tools can still be applied to the research of knowledge building; they tell very little, if any, about the collaborative processes, emergent and progressive understanding, and community knowledge advancements. It has been a challenge for researchers to find and integrate new measures to gain insights into these important aspects of knowledge building.

Over the past decade, researchers have developed a range of measures to analyze and evaluate collaborative learning and knowledge building. These measures fall into three broad categories: (a) content-based analyses to examine student discourse--either online or face-to-face—based on certain coding schemes (e.g., nature of responses, types of questions, depths of ideas, evidence use) (e.g., Hakkarainen, 2003; van Aalst & Chan, 2007; Zhang et al., 2007); (b) behavioral measures that look at student participation and interaction (e.g., contribution rate, reading rate, conversation threads and build-on trees, social networks of who read or respond to whom) (Aviv, Erlich, Ravid, & Geva, 2003; Hewitt & Teplovs, 1999; Howell-Richardson & Mellar, 1996; Zhang, Scardamalia, Reeve, & Richard, in press); (c) linguistic and rhetoric analyses of community discourse (e.g., special vocabulary such as epistemic words and domain keywords, sharing of control) (Hong & Scardamalia, 2008; Sun, Zhang, & Scardamalia, in press). It is generally assumed that the above specific measures all represent important aspects of collaborative learning and knowledge building; the significance of these measures and their interconnections have rarely been tested.

In our recent research, we developed and adapted a set of research tools to examine collaborative knowledge work supported by online environments. These included inquiry threads analysis for mapping out communal knowledge growth by clustering student discourse into conceptual streams, Social Network Analysis for evaluating collective responsibility, content analysis of depth of understanding, and linguistic measures of student discourse, etc. Collectively, these measures help look into the social, cognitive, and linguistic aspects of collaborative knowledge building (Zhang et al., 2007, Zhang, et al., in press; Sun et al., in press). These measures were applied to the same dataset—a grade 4 knowledge building discourse database on light. This presentation reports our secondary analyses of these measures aimed at identifying significant indicators of knowledge building processes.

Method

<u>The Knowledge Building Class</u>

The analyses were applied to the knowledge building work of 22 fourth-graders at the Institute of Child Study, University of Toronto. They studied optics for approximately four months, in line with principles and practices for knowledge building, supported by Knowledge Forum. Overall, students generated problems of understanding, discussed diverse ideas/theories through whole class face-to-face knowledge building discourse, conducted self-generated experiments and observations, searched libraries and the Internet, and shared new resources through cooperative reading. Along with these offline activities, students shared their problems, ideas, data, and resources in their Knowledge Forum database. The teacher experimented with having the whole class collaborate opportunistically to understand optics and to progressively identify important, related issues (e.g., light sources, how light travels, colors, lenses and mirrors, vision). Knowledge Forum provided the public space in which their collective works were recorded, in views corresponding to these goals. This shared resource made this new approach possible. The views helped to keep the top-level goal center front and to keep the structure fluid: small groups formed and reformed based on evolving needs, and sub-goals were identified in related views that were linked and elaborated to enable the structure of the whole to proceed effectively. On a daily basis, students were free to explore any problem from any view in the database. They all took responsibility for the overall growth of the database. Near the end of inquiry, each student wrote a reflective portfolio note about what he/she had learned about light.

<u>Knowledge Building Measures</u>

The primary data source was student discourse in Knowledge Forum. We applied socio-behavioral, content-based, and linguistic measures to the discourse data. These measures are summarized in Table 1.

Table 1. <u>Knowledge Building Measures.</u>

Category	Measures	Explanations
Socio-behavioral measures	Note contribution	# of notes authored per student, as an indicator of their contrition to the community space.
	Note reading percentage	% of notes read per student, as an indicator of knowledge sharing and information spread.

	Note reading network: in-degree and out-degree	Based on social network analysis (SNA) of who read whose notes, the in-degree and out-degree indicate the frequencies of a member receiving and sending out note reading contacts to different members.
	Note linking network: in-degree and out-degree	Based on social network analysis (SNA) of who linked to whose notes (e.g., build on, rise-above, reference), the in-degree and out-degree indicate the frequencies of a member receiving and sending out note linking contacts to different members.
	Note linking network: cliques	In a social network of note linking, a clique is a group of members who have more note linking ties to each other than they are to members who are not part of the group. The number of cliques each student belongs to indicates the level of dynamic collaborations with various members.
Content-based measures	Inquiry threads	An inquiry thread is a stream of discussion that addresses a shared principal problem. The number of inquiry threads a student contributed to as an author indicates his/her diverse participation.
	Problems	# of notes raising or addressing deeper problems.
	Incorporating new resources	# of notes rephrasing or summarizing information from readings, the Internet, or teacher, parent, etc.
	Use evidence	Test and justify ideas with experiments, observations, or life experiences.
Lexical measures	1^{st} 1,000 words	The high proportion of high-frequency words—e.g., the 1^{st} 1000 most frequent English words—in free writing indicates limited vocabulary size and low writing productivity.
	Academic words	Academic words (e.g., theory, hypothesis, approach) are characteristic of academic discourse across different disciplines.
	Domain-specific words	Productive use of domain-specific words as an indicator of the appropriation of disciplinary discourse and knowledge.

Analyses of Knowledge Gains Based on Students' Portfolio Notes

Assessing student understanding through their reflective essays or portfolios has been used and validated by a number of studies (e.g., van Aalst & Chan, 2007; Zhang et al., 2007). In this analysis, we divided each student's portfolio note into idea units—the smallest unit of text that conveyed a distinct idea regarding optics. We first analyzed these idea units in relation to the inquiry themes that had emerged over the optical knowledge building discourse (e.g., how light travels, nature of shadows, eclipses, rainbows, primary and secondary colors, lenses, lasers, cameras, and so forth). The number of themes addressed in a student's portfolio note indicates the breadth of his/her understanding.

To look at the depth of student understanding, each idea unit was additionally rated in terms of epistemic complexity and scientific sophistication. Epistemic complexity indicates students' efforts to produce not only descriptions of the material world, but also theoretical explanations and articulation of hidden mechanisms central to the nature of science (Salmon, 1984). A four-point scale (1 - unelaborated facts, 2 – elaborated facts, 3 – unelaborated explanations, and 4 - elaborated explanations) adapted from Hakkarainen's (2003) work was used to code each idea unit. Scientific sophistication focuses on the extent to which a student has moved from an intuitive framework toward a scientific framework. We coded students' ideas in their portfolio notes on a four-point scale (1 - pre-scientific, 2 - hybrid, 3 - basically scientific, and 4 - scientific), informed by Galili and Hazan's (2000) facets-scheme framework for analyzing students' misconceptions in optics.

Epistemic complexity represents the level of complexity at which a student chooses to approach an issue. The higher the complexity, the larger cognitive efforts he/she needs to devote into its processing. Scientific sophistication represents the level of success a student has achieved in processing an idea at a certain complexity level. It is relatively easy to convey a scientific idea at a factual level (e.g., "we see afterimages when…"), but harder to provide a scientific explanation of a fact (e.g., elaborate causes of afterimages). The meaning of the scientific score of an idea is dependent on the level of its complexity. Therefore, we generated a composite score to indicate the depth of understanding, by multiplying the above two ratings, weighting the rating of scientific sophistication with the level of complexity. For example, an idea rated as "1 - unelaborated facts" and "4 - scientific" will have a composite score of 4, while an idea rated as "4 - elaborated explanations" and "4 - scientific" will have a composite score of 16.

Results

To gauge the relationships between the above knowledge building measures and student understanding, we calculated the correlations between these measures and the breadth and depth of understanding (Tables 2-4).

Table 2. Correlations (Pearson r and p) between the Socio-Behavioral Measures and Understanding

	Notes written	% of notes read	Note reading in-degree	Note reading out-degree	Note linking in-degree	Note linking out-degree	Cliques belonging to
Depth of understanding	.437* (.042)	.398 (.067)	.519* (.013)	.398 (.067)	.431* (.045)	.214 (.338)	.469* (.028)
Breath of understanding	.198 (.377)	.105 (.644)	.308 (.164)	.061 (.788)	.364 (.096)	-.068 (.765)	.159 (.478)

Note. * $p<.05$

As Table 2 indicates, student deep understanding of optics achieved through knowledge building is associated with high note contribution and note reading—both reading others' notes and being read by others—in the knowledge building discourse. Additionally, two of the social network measures of note linking also have significant correlations with depth of understanding. High-achieving students tended to collaborate with different groups of students through note linking (i.e., building on, rising above, and referencing citations), and receive more intensive note links from their peers. There is no significant correlation between the breadth of student understanding and the above measures.

Table 3. Correlations (Pearson r and p) between the content-based measures and understanding

	# of inquiry threads/themes contributed to	# of notes contributing personal ideas	# of notes identifying deeper problems	# of notes incorporating new resources	# of notes using evidence
Depth of understanding	-.034 (.879)	.365 (.095)	.582** (.004)	.403 (.063)	.260 (.242)
Breadth of understanding	1.000*** (.000)	.288 (.193)	.296 (.182)	-.009 (.970)	.056 (.806)

Note. ** $p<.01$, *** $p<.001$

Student deep understanding is significantly ($p<.05$) or marginally significantly ($p<.10$) correlated to their efforts to develop personal ideas, identify and address deeper questions, and incorporate informative resources to help them better understand light. Not surprisingly, the breadth of their understanding they achieved is strongly correlated to the number of inquiry threads/themes they contributed to during the optical discourse.

Table 4. Correlations (Pearson r and p) between the Lexical Measures and Depth of Understanding

	Total words written	Total domain words	Unique domain words	% of the academic words	% of the 1^{st} 1,000 words
Depth of understanding	.646** (.001)	.660** (.001)	.458* (.032)	.506* (.016)	-.646** (.001)
Breadth of understanding	.250 (.262)	.218 (.329)	.594** (.004)	.226 (.313)	-.302 (.172)

Note. * $p<.05$, ** $p<.01$

The depth of understanding is positively correlated to the total number of words students wrote and the frequency of domain words and academic words in their notes; and negatively correlated to the use of the most basic, 1^{st} 1,000 English word families. There is a significant correlation between the breadth of understanding and the number of unique domain words students used in their notes written during the optical inquiry.

Discussion and Conclusions

We applied a set of socio-behavioral, content, and lexical measures to the same knowledge building discourse database. This paper reports our secondary analyses of these measures focusing on their correlations with the depth and breadth of understanding achieved through the knowledge building processes. The results validated a number of discourse patterns characterizing productive knowledge building that can lead to deep understanding. These include: (a) Active contribution to the community knowledge space, indicated through the number of notes and words written; (b) Awareness of contributions developed through note reading; (c) idea-centered, progressive discourse, with students engaged in developing ideas, identifying and addressing deeper problems, constructively using authoritative sources, making productive use of core concepts and academic language to achieve deeper understanding and higher levels of conceptualizations; and (d) collaborative and distributed engagements, achieved through actively building on to the efforts of various members and forming into dynamic teams to address emergent issues at the cross of their interests. Efforts along the above dimensions help to give rise to high-level collective responsibility for community knowledge advancement (Scardamalia, 2002; Zhang et al., in press).

Only two of the measures are significantly correlated with the breadth of understanding achieved through the optical inquiry: inquiry threads contributed to and the number of unique domain-specific words used in the knowledge building discourse. These two measures both point to student participation in multiple inquiry themes, with the use of domain-specific words in the optical discourse being an indicator of both the depth and breadth of understanding.

Knowledge building is a socio-cognitive process advanced through the collaborative discourse of a community. Examining and establishing the significance of the above measures can help researchers validate their research tools to look into the social, cognitive, and linguistic aspects of knowledge building. It also provides a research base for developing automated assessment and feedback tools (e.g., contribution, vocabulary, social networks, automated content analysis) integrated to Knowledge Forum. By providing concurrent feedback data about student performances in these important aspects of knowledge work, we can help teachers and students to reflect on their knowledge building processes and stay on a trajectory of continual improvement.

In sum, this study identified a set of socio-behavioral, content, and lexical measures that are closely associated with student understanding achieved through knowledge building. To better understand the relationships between these measures, we are conducting further analyses using more sophisticated statistical methods (e.g., factor analysis).

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