The Effect of Formative Feedback on Vocabulary Use and Distribution of Vocabulary Knowledge in a Grade Two Knowledge Building Class

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Abstract: This study examines the impact of formative feedback to enhance students' productive written vocabulary. Behavioral, lexical, and network structure analyses were applied to the work of two Grade 2 classes engaged in knowledge building in science. Two variations of feedback including vocabulary and contribution-based visualizations were integrated into the knowledge building practice of the experimental class. Behavioral and lexical measures were calculated with automated tools, and content analysis was used to evaluate depth of understanding. Moreover, the degree of vocabulary distribution throughout the communities was explored. Findings show that formative feedback embedded in knowledge building practices can help students grow their vocabulary, apply new words in productive ways in their writing, and advance community knowledge. Results also show that as students learn and use a more diverse range of words in the context of knowledge building, the more discursively connected they become, and the greater the knowledge distribution across the community.

Introduction

Literacy and the ability to work creatively with ideas are essential competencies for students to develop to become productive citizens in a knowledge society. Literacy as a foundational component of a 21st century education is emphasized in contemporary educational initiatives such as the "Partnership for 21st Century Skills" (see http://www.p21/org). As evident in this framework, literacy crosses all domains and underlies not only core content learning, but also the ability to innovate and collaborate, and to engage effectively with media and technology. In a broad sense, literacy entails an ability to read and write with understanding, use information productively from a range of sources, as well as use language effectively to build and communicate ideas. From a socio-cognitive perspective, developing literacy requires integrating language learning within authentic pedagogical practices that embed language use within inquiry and problem solving processes **(**Applebee, 1981; Bereiter and Scardamalia, 1987). This study explores an integrated approach to language learning that engages young students in creative knowledge work together with literacy practices. It examines how formative feedback supports designed to boost knowledge building discourse impact literacy skills, particularly growth in students' productive written vocabulary. The study also examines the extent to which new and important terms are distributed throughout shared discourse as students worked to collaboratively build knowledge in science.

Knowledge Building for Vocabulary Learning

Knowledge building pedagogy (Scardamalia & Beretier, 2003) is a socio-cognitive approach that can be described as "the production and continual improvement of ideas of value to a community" (p. 1370). This approach places advancement of community knowledge as the explicit and shared goal (Scardamalia, 2002). In knowledge building, students work together to participate in creative work with ideas in the effort to produce increasingly coherent explanations to shared problems of understanding. Knowledge building practices are enhanced by Knowledge Forum, an online environment specifically designed to support high-level knowledge work (Scardamalia, 2004). Knowledge building affordances embedded within the environment include the ability to co-author, reference, or build-on notes; scaffolds support high-level discourse moves such as "My theory," "I need to understand," or "This doesn't explain" to help frame thinking and writing, automated assessment tools support evaluation and exploration of discourse. Both online and offline, a knowledge building approach fosters collaboration and creative knowledge work, with shared discourse as its driving force. As such, it provides a rich context to engage students' in authentic literacy practices that involve individual and co-operative reading, writing, idea development, active research, and sustained collaborative dialogue (see Sun, Zhang, & Scardamalia, 2010).

As elaborated above, literacy is bound up with processes of productive knowledge work. A critical aspect of literacy involves use and growth of vocabulary. Research has shown that greater knowledge and use of vocabulary is a reliable predictor of reading and writing comprehension (Stahl, 1991) as well as verbal and

listening skills (Steahr, 2009). Studies also show that learning a new word is not a singular event, but happens over time, with increased and varied usage indicating deeper understanding (Nation, 2001). Integrated contexts of literacy that promote productive vocabulary use and growth thus engage students in meaningful activities related to new or difficult words, expose them to multiple and varied encounters with these words, and give them opportunities to utilize such words in speaking, reading, writing and listening (Stahl, 1991). Authentic literacy practices engage students in these activities not only in the interest of language acquisition, but in the service of authentic inquiry and problem solving; such instructional environments have been shown to be more effective for language learning than direct instruction with respect to depth of word knowledge, writing quality and expansion of vocabulary (Yonek, 2008; Stahl, 1991). With its focus on immersing students in shared discourse for solving problems of understanding, knowledge building practices present conditions highly conducive for effective vocabulary learning. Students are offered rich opportunities to introduce new vocabulary within inquiry-based work, negotiate and infer word meanings, and use available sources to help them deepen their knowledge of new words.

In this study, we explore the discourse of two grade 2 classes as they each engaged in two knowledge building units in science, with a focus on the life cycles of birds and salmon. We focus on development of productive written vocabulary as evidenced in students' writing on Knowledge Forum. Productive use of vocabulary entails that students display a diverse range of words in their writing in a way that conveys understanding. Richness in student vocabulary includes use of both domain-specific and epistemological terms or "academic words" (Coxhead, 2000). Productive use of domain-specific vocabulary is indicative of grasping core content and language, with frequent use of domain specific words indicative of integration into a discursive community (Chernobilsky et al., 2004). Similarly, "academic words" (eg. source, theory, hypothesis) refers to terms that occur at a reasonably high frequency rate in academic discourse; these words cross domains and generally correspond with higher level knowledge work. Academic words typically appear in students' discourse at a relatively late age, beginning in adolescence and increasing with post-secondary education (Laufer, 1994).

So, is it plausible to expect children of primary school age to use sophisticated vocabulary in their written work? According to research on reading progression (Chall, 1996), the spectrum of learning across which both reading comprehension and vocabulary usage take place is characterized by important developmental changes. According to this framework, in primary level grades students are still "learning to read"—gaining foundational phonetic knowledge—rather than "reading to learn", which involves higher level cognitive processes and does not begin to take place until approximately grades 4-6 (Chall, 1996). However, this progression is not a rigid series of sequential stages, but an overlapping continuum that is based on approximate grade and age levels; furthermore, the developmental steps are dependent to a considerable extent upon the learning environment itself (Chall, 1996).

Research shows that exposing students to specialized fields of discourse on a repeated basis in authentic language-learning settings can help foster the productive use of sophisticated words (Corson, 1997). Immersing students in settings that include speaking and listening along with reading and writing is particularly beneficial for lower-level readers (Beimiller, 1999). Similarly, research shows that even with a single exposure, a word encountered in a richer context is more likely to be learned than is one in a less rich context (Herman, Anderson, Pearson, & Nagy, 1987). Combining reading and writing activities with explicit vocabulary learning has been shown to be a highly effective strategy for language learning (Stahl & Fairbanks, 1986). In addition, the use of formative assessments to enhance learning is widely recognized (Black & William, 1998; Stiggins, 2004; Marzano, 2006). Formative assessments integrated within computer-supported learning environments have also been shown to be beneficial for learning (Tseng & Tsai 2007). Moreover, studies show that vocabulary-based feedback such as word or tag clouds provide useful overviews of knowledge that highlight key concepts (Hearst and Rosner, 2008) and aid in semantic exploration and comprehension of data by users (Bateman, Gutwin, and Nacenta (2008).

These findings support the notion that even students as young as the second grade can learn and use complex vocabulary productively if conditions and resources are conducive to such learning. A knowledge building approach has been shown to provide such conditions. For example, research has shown gains in vocabulary and comprehension as by-products of collaborative and creative work with ideas—knowledge building contexts with no direct focus on vocabulary learning and text comprehension (Scardamalia et al., 1992). Furthermore, children as young as junior kindergarten have shown gains in literacy using this approach (Pelletier, Reeve, & Halewood 2006). Looking at vocabulary growth in knowledge building students across grades 3 and 4, Sun et al. (2010) traced an increase of use of academic words of almost four percent on average, and found positive correlations between use of sophisticated vocabulary with depth of understanding. Where benefits in knowledge building work for literacy are reported, this study will be the first to focus on the role of formative feedback targeted to enhance students' vocabulary knowledge. Moreover, examining students' knowledge building calls for collaborative, emergent knowledge advancement in addition to individual assessments. This study will also

address learning gains at the group level by looking at the underlying network structure of rich vocabulary in the collective discourse to determine the extent to which vocabulary use is distributed throughout the community.

Method

Participants and Classroom Context

Participants for this study include 44 Grade 2 students attending the Dr. Eric Jackman Institute for Child Study in downtown Toronto. Two consecutive Grade 2 classes were studied—22 students (11 boys, 11 girls) from the 2010-11 grade 2 class, and 22 students (11 boys, 11 girls) from the 2011-12 school year. Both classes were taught by the same teacher, and engaged in the same activities for each knowledge building unit. For their knowledge building sessions, both Grade 2 classes split up in a rotation in which half the students went to the library and the other half engaged in inquiry. The 2010-2011 class was not subject to any treatments and provides what we will call the "benchmark" class. The 2011-2012 class functions as the experimental class. Within this class, two student groups (Group A and Group B) each received a different variation of the treatments, which are elaborated below.

Both Grade 2 classes in this study participated in a four month "Bird Study" knowledge building unit followed by a 4 month unit on "Salmon". For both units, the Grade 2 students typically had one 45-minute session a week dedicated to knowledge building, referred to as "KB" time. During this period, students engaged in active research or whole group "KB talks" in which they discussed questions, ideas, and so on, related to their area of study. Typically, students were given 20 minutes to enter their ideas, questions, theories, etc., into the Knowledge Forum community space. For both units of study, students engaged in active research and used a variety of sources, including books, websites, and videos, to increase their knowledge on birds and salmon. Students in both classes also examined objects such as owl pellets, feathers, and nests, as well as raised salmon in a classroom tank as part of the "Lake Ontario Salmon Restoration Program". Thus, students in both years had rich environments to support their knowledge building work. Although students were split into groups during knowledge building time in both classes, all students in a single class worked in the same knowledge space.

Design

Four knowledge building principles served as important design elements for this research, informing the two different treatments embedded in the knowledge building practices of the experimental class:

(i) Knowledge Building Discourse: This type of discourse constitutes collaborative dialogue that focuses on continual refinement and improvement of ideas and advances through a community's continued efforts to deal with puzzling facts. An element of knowledge building discourse includes occasional periods of reflection on the state and direction of the community's discourse itself. "Meta-discourse" can be described as discussion about discussion, and calls for community members to take a "meta-perspective" on their own dialogue. Meta-discourse serves as a type of formative evaluation that can help a knowledge creating community both assess their achievement up to the current point and decide on a future plan of action. Van Aalst (2009) identifies meta-discourse as a key condition of an innovation ecology that can enable knowledge creation. Studies also show that meta-discourse can help students in a range of important ways, such as recognizing shared knowledge advances, identifying setbacks, plotting out next steps, setting goals and drawing links between them, connecting ideas, articulating new and promising questions, and establishing deeper ties between authoritative knowledge and newly identified problems (Zhang et al., 2009; Zhang & Messina 2010; Zhang et al., 2011). In this study, special "KB Talks" devoted to meta-discourse were integrated within the students' inquiry time as a pedagogical treatment geared towards enhancing students' knowledge building dialogue. Questions addressed in these sessions included: Are we answering our questions; are we going deeper with our theories; are we bringing in useful information that is helping us develop our ideas; are we stuck on a problem; what can we do to get "unstuck"? While both 2011 and 2012 classes engaged in collaborative discourse both on and offline, the experimental 2012 class was subject to a series of special "KB talks" that focused on engaging students in meta-discourse. Both Group A and Group B participated in a total of eight meta-discourse sessions over the course of eight months.

(ii) Concurrent, transformative and embedded assessment: This principle speaks to the effort, on behalf of the community itself, to identify advancements or setbacks in its knowledge building endeavors on a continual basis. To help facilitate meta-discourse sessions, students in the 2012 class were given formative feedback in the form of simple visualizations to help them take a "bird's eye view" of their own discourse. Two forms of feedback were tested: a.) Word Clouds—Students in both Group A and Group B were shown a series of different word clouds that visualized key concepts and vocabulary relevant to streams of inquiry that emerged in their own discourse. The aim was to introduce and further acquaint students to new or challenging words in a context deeply integrated with their knowledge building work. In this study, three different types of word clouds were used (see Figure 1): those that depicted the most frequent terms the students were using in their naturally-occurring dialogue over time ("Our Words"); those that depicted key words that experts frequently used when talking about those same phenomena ("Expert Words"); and a third which allowed students to see the extent to

which the words characterizing their discourse mapped onto the "expert" dialogue, by means of colour-coding ("Our Shared Words"). For instance, the expert terms featured on the "Expert Words" cloud that students were engaging in their own online discourse were coloured red on this visualization, while terms that students had not yet used remained black. While visualized to the experimental class by means of the word clouds, the "expert" vocabulary was available to both classes via research materials in the classroom, including books that were read or objects that were discussed during KB talks.

All word clouds were refined throughout the inquiry, with changes based directly on terms emerging from students' writing on Knowledge Forum. These visualizations would help students gain a sense of the semantic field of their discourse, and would enable the community to trace the use and longevity of new terms in a discourse over time. For instance, growth and change of the "Our Words" cloud helped to make explicit the attention that different terms were receiving at different points in time, displaying to the community which terms were dominating the discourse, which potentially significant terms remained underused or unrecognized, whether terms stayed relevant or useful to the problem at hand, and so on. Lack of common vocabulary between students and authoritative sources, as evidenced in the "Our Shared Words" cloud, could show limits of student understanding while also depicting terms that could help to fruitfully expand the dialogue. Embedding discussion of these visuals into meta-discourse sessions was designed to help position them as objects of public discourse that helped to make explicit important elements of the online dialogue as it emerged and to serve as artifacts the community could rally around during group reflection.

Figure 1. Visualizations supported meta-discourse, including Word Clouds (left) and Meta-Discourse tool (right)

b.) Meta-Discourse Tool—In addition to word clouds, students in Group B were exposed to the Meta-Discourse tool (see Figure 1). This is a new tool embedded within Knowledge Forum that is specifically designed to help students take a meta-level perspective on their own discourse, and to support meta-discourse by giving students explicit feedback about the contribution makeup of their group dialogue at any given time. This tool allows students to monitor the types of discursive moves—corresponding to the scaffolds in Knowledge Forum—used by their community at any given time. While both groups in the experimental class participated in meta-discourse sessions, Group B was introduced to the Meta-Discourse tool from the first treatment in order to chart the contributions on their own working view, and used the graphs produced by the tool to mediate their reflective discussions in each of the eight sessions. Both the word cloud and the meta-discourse visualizations were shown to the whole class.

(iii) *Constructive use of authoritative sources:* This principle requires that students engage with "expert" texts and information in a way that is both critical and conducive to improving their own ideas. This practice involves encountering unknown terms and concepts, and applying them to students' own ideas. In the experimental class, students were encouraged to explore unknown words and find relevant sources to help them understand new or challenging vocabulary. After meta-discourse discussions students moved onto writing in Knowledge Forum, often forming small groups or working in pairs to find resources to help them learn more about the important terms just discussed. Students engaged in co-operative reading, writing and discussion about these words, and worked to acquire definitions of new words as well as integrate them into group discourse.

(iv) *Symmetrical knowledge advancement*: This principle implies that knowledge and expertise flows within and between community members working on shared problems in the interest of improvement of ideas. The distribution of knowledge across a community is important in the context of vocabulary learning, especially in the early years. Research shows that children who acquire literacy skills in the early years of schooling are more likely to experience success at higher levels of education, with the reverse also holding true (Stanovich, 2000). Simply put, children who know more words can learn more words (Stahl, 1991). The collaborative meta-discourse discussions, coupled with visualizations designed to give students a meta-level perspective on critical aspects of their own discourse, were aimed at engaging all students in various literacy practices including reading, speaking, listening as well as writing, so that productive vocabulary use was distributed throughout the group discourse.

It is our hypothesis that students in the experimental class will demonstrate a greater degree of productive written vocabulary than the benchmark class from the previous year. We also predict that the more expansive the vocabulary, the greater the knowledge advancement of the community. Moreover, we predict that vocabulary use in the experimental class would be used and distributed across time and groups to a greater

extent than in the benchmark class. We also hypothesize that Group B from the experimental class would contribute more diversely than Group A or the benchmark class, and correspondingly exhibit greater knowledge advancement.

Data Analysis

The data source for this study was student discourse as archived on two Knowledge Forum databases generated over two consecutive years. These include: i.) Grade 2, 2011—248 notes across four views, from both the "Bird Study" (114 notes, 3 views) and "Salmon Study" units (134 notes, 1 view); ii.) Grade 2, 2012—203 notes across eight views from their "Bird Study" (175 notes, 7 views) and "Salmon Study" (90 notes, 1 view) units; and iii.) video of student "KB talks" and meta-discourse sessions supplement notes and provide qualitative information about students' ideas.

The application of behavioural, lexical, and group-level dynamics, are summarized as follows:

(a) <u>Behavioural Measures:</u> The Knowledge Forum Analytic Toolkit (Burtis, 1998) was used to calculate the number of notes authored per student and the percentage of notes read per student.

(b) <u>Lexical Measures</u>: Lexical profiles were calculated for each student using the Knowledge Forum Analytic Toolkit. Researchers manually corrected spelling errors so that all words could be picked up by the automated tools. Three attributes were used to create students' lexical profiles, and include the following: i.) academic words; ii.) 1st, 1000 words; iii.) domain-specific words. The Academic Word List (AWL) is composed of 570 written families external to the 2000 most frequently used English words but common in academic discourse. The 1st, 1000 words refers to a lexicon consisting of the most frequently used words in English, plus their grammatical variations. Greater use of high frequency words is indicative of a more limited vocabulary (Nation, 2001). With respect to domain-specific words, two inquiries were conducted to generate a single word list. Firstly, researchers consulted the Ontario Curriculum Standards document for Science and Technology and identified key words corresponding to the "Understanding Life Systems" stream. The words selected totaled 342 individual terms that ranged across Grades 1-10. Words selected from the curriculum document were divided into two levels according to the grade in which they appeared in the curriculum document. 84 words were identified at or below the Grade 2 level, and 258 words above the Grade 2 level. In addition to this, the author and classroom teacher consulted the external sources available in the classroom and identified terms critical to particular streams of inquiry as they emerged during the course of knowledge building work. These words appeared on the word cloud visualizations to help students expand their vocabulary repertoire. For analysis, a total of 64 "expert" words were combined with the 342 curriculum words to create a single comprehensive list. This cumulative list, which totaled 406 words, plus their grammatical variations, was used to measure domain-specific vocabulary.

(c) <u>Depth of Understanding</u>: To examine community knowledge advancement, two researchers used content-based analysis to select notes from the online discourse that represented "theorizing" work (see Chuy, Resendes, Tarchi, Chen, & Scaradmalia, 2011). Such notes exhibit students' explicit attempt to produce explanations and express original ideas, and as such comprise useful examples of students' productive writing and their ability to convey conceptual understanding. To evaluate depth of understanding, "theorizing" notes were then subject to further analysis according to two coding schemas developed by Zhang and colleagues (2007) to measure "scientificness" and "epistemic complexity" of ideas, each possessing four levels. Scientificness implies the degree to which an idea is scientifically accurate, while epistemic complexity represents the level of cognitive effort and written sophistication evident in an explanation. The level of idea complexity informs the meaning for scientificness, so scores for each note were multiplied for a single composite value (Zhang & Sun, 2008).

(d) <u>Group Discourse Network Structure</u>: On a group level, notes were analyzed using KBDeX **(**Matsuzawa, Oshima, Oshima, Niihara, & Sakai, 2011**)**, a tool developed for Knowledge Forum that is designed specifically to analyze the network structure of collective discourse based on co-occurrence of words. KBDeX can reveal the network structure of a community's discourse according to three levels. Firstly, it analyzes interconnectivity between students via shared vocabulary on a social level; secondly, it maps discursive connections on the level of individual notes, which shows the use and distribution of vocabulary in students' writing; lastly, it traces connections at the level of individual words, which reveals semantic relationships between words and the conceptual content of the discourse. For this study, we analyzed each class's discursive network on the social and individual word levels according to Degree Centrality (DC), Betweenness Centrality (BC) and Closeness Centrality (CC), which represent standard points of analysis in complex network science (e.g., Newman, 2010). Degree centrality measures the "popularity" or number of connections one node has with other nodes in the network. In this case, each network node represents a student or a word, with connections between students created through the use of the same word, and connections between words created when one word appears in the same written note as another word. So, the more discursive connections a student has with other students, or a word with other words, the more "popular" or centralized that student or word is in the network. Betweenness centrality provides a valuable measure at both a local and global level, and indicates the degree of connectivity of a node, as well as the "load" placed on the node by all other nodes. For this research, this measure reveals the

extent to which students or words are connected within a community and the degree to which they bridge various social clusters or discursive cliques, respectively. Closeness centrality measures the proximity of one node to all other nodes, and is indicative of how quickly information can flow through a network. Applied to this case, this measure reveals how closely connected students are to each other via the discourse they are engaging in, or, in the case of words, the semantic context in which they are being used. The particular domain-specific and academic words used by the students in each class, generated from their lexical profiles, were used to comprise two separate word lists for group analysis in KBDeX. In this way, the discursive relationships between students and words characterizing the collective discourse could be mapped.

Results

Did the experimental class show more productive written vocabulary than the "benchmark" class?

To explore significant differences across groups in student performance on behavioral and lexical measures, as well as on their demonstrated depth of understanding, a one-way ANOVA was conducted for each measure. Results show significant differences for the following measures: total domain words, $F(2, 43) = 7.77$, $p < .01$; unique domain words $F(2, 43) = 5.62$, $p < .001$; total words $F(2, 43) = 3.44$, $p < .05$; use of words above Grade 2, $F(2, 43) = 7.24$, $p < .001$; and depth of understanding $F(2, 43) = 11.5$, $p < .001$. Post-hoc tests (HSD) revealed that Group B used significantly more domain words in total ($p < .001$, Cohen's $d = 9.72$), as well as more unique domain words ($p < .01$, Cohen's $d = 5.91$) than the other two groups. Furthermore, Group B wrote significantly more words than Group A ($p < .05$, Cohen's $d = -72.64$), and both Group A ($p < .01$, Cohen's $d = 2.96$) and Group B ($p < .05$, Cohen's $d = 2.35$) outperformed the 2011 class with respect to use of words above Grade 2. These results suggest that formative feedback that is embedded in knowledge building practice helps young students to use increasingly rich and diverse vocabulary. These findings also suggest that visualizations reflecting student contribution patterns to group discourse prompt students to write more in total.

With respect to depth of understanding, both Group A ($p < .001$, Cohen's $d = 2.45$) and Group B ($p < .01$, Cohen's $d = 1.79$) performed better on depth of understanding than the 2011 class. This suggests that formative feedback coupled with collaborative reflective discussion can help students construct and communicate ideas in writing that reflect greater scientific accuracy and more elaborate explanations. Within the 2012 class, Group B wrote significantly more words than Group A, as noted, yet there was no significant difference in depth of understanding between groups ($M = 5.13$, $SD = 2.15$ vs. $M = 4.48$, $SD = 1.12$, respectively). A closer look at student work reveals that within Group A, a few students stood out as having especially high composite scores, which could help to explain group performance on this measure.

To what extent was key vocabulary distributed in the shared discourse?

The continual give and take of ideas to advance community knowledge is a foundational principle upon which knowledge building communities operate. In order to explore group-level dynamics in the community and the shared discourse, network structure analysis was conducted using KBDeX. As elaborated in a previous section, typical knowledge building sessions in both Grade 2 classes involved students splitting up into rotating groups. However, all students in both classes worked in the same knowledge space on the database and contributed their ideas to a shared online discourse. For this reason, group-level analysis was conducted across the 2011 and the 2012 class as a whole with this tool.

To explore any significant differences across classes with respect to the degree, betweenness and closeness centrality of each student community, a one-way ANOVA was conducted for each measure. A significant difference was found for both degree centrality $F(2, 41) = 11.17$, $p < .0001$ and betweenness centrality $F(2, 41) = 13.46$, $p < .001$. Post-hoc tests showed that both Groups A ($p < .01$, Cohen's $d = .17$) and B ($p < .001$, Cohen's $d = .19$) displayed greater degree centrality than the 2011 class. Furthermore, the benchmark class showed greater betweenness centrality than both Group A ($p < .001$, Cohen's $d = .0091$) and Group B ($p < .001$, Cohen's $d = .0090$). No difference was found with respect to closeness centrality. These findings indicate that the 2012 class community had a higher number of students who had a higher number of connections with other students, suggesting that a greater number of students were using more shared words more often. Moreover, a higher betweenness centrality indicates that there were more social clusters in the 2011 class, as opposed to the 2012 class in which each student was more highly connected to every other student. However, that the 2011 class also exhibits a highly connected community, albeit to a lesser degree than the 2012 class, indicates that knowledge building practices are themselves conducive to knowledge distribution across the community. In general, these results suggests that as students learn and use a more diverse range of words in the context of knowledge building, the more discursively connected they become, and the greater the vocabulary knowledge distribution across the community.

The same series of tests were conducted to trace differences in the network structure of individual words. A significant difference across groups was found for closeness centrality, $F(2, 43) = 3.34$, $p < .05$, with

the students in Group B using terms that were more semantically bound together in their discourse than in either of the other groups. This group of students exhibited more diverse vocabulary, as their discourse contained more terms semantically-related to those of other students. This condition is conducive to vocabulary learning as students have access to a wider range of vocabulary in a collective knowledge pool, and this appears to foster higher levels of word-associations leading to use of these terms in different contexts. In terms of degree centrality and betweenness centrality, no significant differences were found. This suggests that engagement in knowledge building practices encourages active use of important vocabulary in writing and making connections across various discursive streams in collective dialogue.

Discussion and Conclusions

This study explored the impact of formative feedback visualizations embedded within knowledge building practices to students' productive written vocabulary. Student work was analyzed on two levels. First, vocabulary use was assessed by calculating behavioral and lexical attributes. Content analysis was used to evaluate depth of understanding, as demonstrated in student online discourse. Second, the distribution of vocabulary use throughout the community was explored through network structure analysis of discourse on the level of students and words.

Results show that formative feedback that is productively integrated into authentic inquiry practices can facilitate vocabulary growth, use of new words in students' writing, and advances in community knowledge. On the whole, students in the experimental class used more domain-specific vocabulary more often and exhibited greater scientificness and complexity of ideas than students in the benchmark class. Within the experimental class, students who received formative feedback related to both vocabulary use as well as feedback regarding the various ways they were contributing to group dialogue, used more sophisticated words than students who only received feedback regarding vocabulary, but did not show greater knowledge advancement. This suggests that the vocabulary use for students receiving both kinds of feedback extended more widely beyond their theorizing work and into different contribution types, such as asking questions or reporting facts. It also suggests that engaging students in rich reflective discussion around formative feedback has a positive effect on students' knowledge advancement. Based on these findings, one possible recommendation for primary grade teachers is to encourage group reflection consistently throughout a knowledge building study, since meta-discourse sessions proved fruitful even for students as young as Grade 2. Another recommendation is that teachers take advantage of group discussion periods to integrate feedback visuals for students to collaboratively explore.

Finally, network structure analysis of students' collective discourse showed that all students in the experimental class were more discursively connected to one another and made more connections with other students via their shared discourse than students in the benchmark class. That this distribution of vocabulary knowledge is evident in Grade 2 is promising given that the disparity between students who demonstrate high literacy skills and those who show lower level skills accelerates notably after the primary level and into the junior grades. Results also suggest the importance of supporting meta-discourse, enhanced by formative feedback, as a routine component of knowledge building practice with young students.

Further research that explores students' verbal dialogue in addition to the content of their online contributions is needed to more fully explore and assess primary aged students' literacy levels and capacities for expanding vocabulary knowledge. Also, to better understand the impact of formative feedback on developing students' capacities in literacy concurrent with knowledge building, future research will focus on refining feedback designs and examining a wider range of literacy and knowledge distribution indicators.

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