A Review of Assessment Tools of Knowledge Building: Towards the Norm of Embedded and Transformative Assessment

Gaoxia Zhu, University of Toronto, gaoxia.zhu@mail.utoronto.ca
Mi Song Kim, Western University, mkim574@uwo.ca

Abstract: Drawing upon socio-constructivism, the success of knowledge building involves the social, cognitive and emotional dynamics. Embedded and transformative assessment is essential to assess the dynamics, and some assessment tools have been developed. However, what the affordances of these tools are, which level discourse these tools assess, what these tools focus on analyzing, and how teachers use them are not clear. In this study, we reviewed the assessment tools and empirical studies in which these tools were adopted. We found based on the affordances of the tools and the accounts provided by the authors, the tools could be classified into: activity monitoring tools, social network tools, discourse level analysis and meta-discourse level analysis. Most of the tools focus on analyzing both community and individual level discourse. Moreover, existing research mainly focuses on the meta-cognitive and socio-cognitive aspects of knowledge building processes. Teachers played critical roles in co-investigating the technical and pedagogical designs, and usually several tools were adopted in a study. This research implies that we need to explore more holistic approach to study the relationships between the emotional, cognitive, and social dynamics of Knowledge Building and design more integrative and informative assessment tools.

Introduction

Social constructivism describes learning as social interactions and dynamics with an emphasis on the importance of culture and context (Kim, 2013; Derry, 1999; McMahon, 1997). From the perspective of social constructivists, both external factors (e.g., social environment) and internal factors (e.g., individual cognition) play roles in the process of knowledge construction (Woolfolk, Winne &Perry, 2009). Knowledge Building is a socio-constructivist approach with theory, pedagogy and technology aligned. Students take collective responsibility for improving ideas, pursuing more powerful explanations and theories as a community (Scardamalia & Bereiter, 1994, 2014). Community knowledge is emphasized to reflect the commitment to public knowledge—ideas that live in the world, not simply in individual minds (Popper, 1972).

Scardamalia (2002) outlined twelve principles that describe the priorities of Knowledge Building pedagogy and help distinguish Knowledge Building from the approaches on the spectrum of constructivism, such as Problem-Based Learning (e.g. Barrows, 1985), Project-Based Learning (Hmelo-Silver& Barrows, 2008) and Fostering Communities of Learners (Brown, 1997). The principles are closely interconnected (Scardamalia, 2002) and provide some sense of ways in which cognitive, social and emotional constructs are deeply intertwined and inseparable. For example, students work on real ideas and authentic problems – ideas that arise from their efforts to understand the world in and out of school and across subjects; empathy and social commitment are reflected in collective responsibility "for knowing what needs to be known and for ensuring that others know what needs to be known" (Scardamalia, 2002, p.2) to deal with the emergent and unpredictable needs of knowledge work; to foster knowledge to flow within and between communities, the classroom culture must be psychologically safe, inclusive and cohesive (Bateman, Goldman, Newbrough, & Bransford, 1998) so that students may feel free to "reveal ignorance, voice half-baked notions, give and receive criticism" (Scardamalia, 2002, p.9). Well-being comes from identification with a civilization-wide effort to advance frontiers of understanding.

Another key principle of knowledge building is "embedded and transformative assessment" (Scardamalia, 2002). Assessment is part of the effort and process to advance knowledge (Scardamalia, 2002). It is used to help teachers and students understand the state of their discourse as well as identify problems as the work proceeds. The teacher who adopts Knowledge Building approach helps students be responsible for their own learning, and students directly engage in high level cognitive work such as goal-setting, planning and monitoring. Students may go very deeply and diversely by writing, building on, rising-above, annotating, and referencing to diverse ideas in Knowledge Forum – a software environment developed to support Knowledge Building practice (Scardamalia, 2004), which may make the teacher and students feel uncertain of what is going on (Philip, 2009). This issue requires assessment tools to help analyze the state of community knowledge and the interaction between community members/ideas to identify the knowledge and contributing gaps, and to reveal the emotional state so as to make the teacher and students feel comfortable.

Collaboration is valued in knowledge building, and assessment of knowledge building should focus on collaborative processes rather than on the individual level. The emphasis on the individual is problematic since ideas do not belong to the speakers of authors who first contribute them but belong to the public space where all

community members can collaboratively improve the ideas through public and progressive discourse (van Aalst & Chan, 2007). However, it should be noted that group level analysis does not exclude individual analysis, rather, acknowledges the existence of different levels of analysis (i.e., at the individual, the small group and the whole community level; see Stahl, 2015; van Aalst & Chan, 2007).

In the past decades, a bunch of assessment tools have been developed to assess knowledge building discourse and help community members to improve ideas. These tools are embedded in Knowledge Forum or exist independently. However, what the affordances of these tools are, which level discourse these tools assess, how teachers use these tools and what these tools focus on analyzing (e.g., the social, cognitive or emotional dynamics) are not clear. This review aims to analyze the existing tools that support knowledge building discourse and empirical research in which these tools were adopted. Questions that guide this research are:

(1) What are the affordances of the assessment tools to support individual, community or both level discourse?
(2) What do these tools in empirical studies assess, the social, cognitive, and/or emotional dynamics of Knowledge Building, and how do teachers use these tools?

Method

We examined the supporting tools embedded in Knowledge Forum 4, 5 and 6 and independent tools developed and used by the experts in this area. Then we used the name of each tool and "knowledge building" as keywords to retrieve articles in which the tools were described and used to foster knowledge building discourse using Google Scholar.

We synthesized and classified the tools based on their affordances and the accounts provided by the authors. Given the frequent presence of tools providing statistics summaries on individual or community activities in a Knowledge Forum database and tools analyzing the social interactions between students in empirical studies, we extracted the categories of activity monitoring tools and social network tools. Chen and Zhang (2016) indicated that choice-based analytics could be classified into three levels: choice-making among emergent ideas, among emergent themes or high-order conceptual structures and of discourse moves. Drawing upon their classification, we categories some tools as discourse level analysis and meta-discourse level analysis based on whether a tool focusing on analyzing concepts emerged in students' discourse or requiring students to engage in meta-discourse to identify ideas/themes or threads they wish to work on. If a tool fell into more than one category based on its affordances, we followed the accounts provided by the authors when assigning it. For example, the Knowledge Connection Analyzer (KCA, van Aalst, Mu, & Yang, 2015) not only provides the frequency and percentage of notes being read, build on and referred to, scaffolds used, keywords introduced, but also questions for students to reflect on the gap of their work and how to move collective knowledge forward. Since the authors described it as a software to support students' self-assessment of online discourse, we assigned it to the discourse level analysis category. For each category of the tools, we analyzed which level discourse the tools assess, how teachers use them, how they support the social, cognitive and emotional dynamics of Knowledge Building and their efficiency in empirical studies.

Results

We found 17 assessment tools to respond to our research question, and classified them into four categories: activity monitoring tools, social network/semantic-social relationship tools, discourse level analysis and meta-discourse level analysis. The description of each tool and related examples are shown in Table 1.

Table 1. Assessment tools for Knowledge Building

Categories	Affordances	Assessment level	Assessment Focus	Examples
Activity monitoring tools	Providing quantitative summaries of student contributions such as the number of authored notes, used scaffolds and daily activities	Individual and community	Quantitative summary	*Analytic Tookit* (Burtis, 1998), *Epistemic Discourse Moves Tool* (Resendes, Scardamalia, Bereiter, Chen, & Halewood, 2015), Activity Dashboard, Note Dashboard, Contribution Summary
Social network/semantic-social relationship tools	Exploring social structures within a community by analyzing students' reading, building-on and referencing interactions or semantic relationships between notes	Mainly community level	Socio-cognitive	*Social Network tool* (Hong, Scardamalia, Messina, & Teo, 2015), *Knowledge Building Discourse* eXplore (KB DeX, Oshima, Oshima, & Matsuzawa, 2012), *Rotating*

				leadership analysis (Ma, Matsuzawa, & Scardamalia, 2016)
Discourse level analysis	Analyzing the vocabulary/concepts students used in their discourse from different perspectives such as the growth of vocabulary, the comparison of vocabulary used in students' notes and in pre-defined dictionaries, and the overlapping of vocabulary in different notes	Individual and community	Socio-cognitive	*Comparative Word Clouds* (Resendes et al., 2015), WordWhispers (Chen & Liu, 2016), *Vocabulary Analyzer* (Hong, et al., 2015), *Semantic Overlap Tool* (Hong et al. (2015), Lexical Analysis (Laferrière, Hamel, Hamel, Perreault, & Allaire, 2016)
Meta-discourse level analysis	Planning, monitoring and evaluating ideas/themes or threads in community discourse	Mainly community level	Metacognitive	*Promising Ideas Tool* (Chen, Scardamalia, & Bereiter, 2015), *Idea Thread Mapper* (*ITM,* Zhang et al., 2015), *KCA (*van Aalst, et al., 2015), *Wiki page* (Hewitt & Woodruff, 2010)

* The tools in italic have been tested in empirical studies.

Affordances of the assessment tools

Activity monitoring tools

Activity monitoring tools provide quantitative summaries of student contributions. For instance, the Analytic Toolkit provides summary statistics on individual and community level activities in a Knowledge Forum database, including database overview, single author report, reading, building on, referencing interactions and so forth (Burtis, 1998). The Epistemic Discourse Moves Tool (Scaffold Growth) displays bar graph of frequency of use of Knowledge Forum scaffolds such as "I need to understand", "Important information+source" and "My theory". This allows to track the scaffolds used by selected students in selected views during different time (Resendes et al., 2015). The Activity Dashboard shows the number of daily activities (creating, reading, modifying) across timeline, while the Note Dashboard displays the number of daily contributed notes. The Contribution Summary displays individual's total contributions (authored notes, co-authored notes, drawings) during different time. All these tools can assess individual and community level contributions.

Social network/semantic-social relationship tools

Social network tools help students explore the social structures within a community by analyzing agents' social relationships (e.g., interaction exists between two agents if one reads, builds on, or refers to another's note) or the semantic relationships between notes (e.g., co-occurrence of words in notes). For instance, the Social Network Tool assesses group dynamics or community members' interactivity in terms of building on, linking to, referencing, annotating, or other ways. It uncovers whether community members are collaborating with others as indicated by building on their work (Hong et al., 2015). KBDeX explores semantic network structures of collective discourse and displays dynamic learner network, word network and discourse unit network (Oshima et al., 2012). Nodes in the learner network represent learners, and they are connected if learners share more than one word in their discourse unit (what is called note in Knowledge Forum). Nodes in the word networks represent the input key words, and nodes are connected if co-occurrence of the words is found. Nodes in the discourse unit network represent notes, and nodes are connected if more than one word is shared in the notes. Adopting KBDeX, the rotating leadership indicator employs agents' semantic-social relationships and considers the student with the highest betweenanes centrality in the learner network based on input key terms as the leader of that moment.

Discourse level analysis

Some tools analyze the vocabulary/concepts students used in their discourse from different perspectives. For example, Comparative Word Clouds include three components: (1) "Our Words" that students used in their Knowledge Forum notes based on using frequencies; (2) "Experts' Words" used in authoritative resources on the same theme, and (3) "Shared Words" appeared both in students' notes and authoritative resources (Resendes et al., 2015). WordWhispers recommends potentially useful words to help students create

or revise a note in an unobtrusive manner (Chen & Liu, 2016). It extracts words from the current note that a user is editing, and retrieves a list of most related words to the current note or the most dominate words in the view where the note lives if the note is empty. The Vocabulary Analyzer (Vocabulary Growth) traces an individual's vocabulary growth over time and assesses the vocabulary level against input words (Hong et al., 2015). The Semantic Overlap Tool indicates the overlapping words or phrases extracted from different notes (or sets of notes) by comparing them. It identifies the overlapping terms in student discourse and curriculum guidelines, and determines idea similarity between notes based on the key terms they contain (Hong, et al., 2015). Lexical Analysis compares words used in discourses with preset lists of concepts or specified dictionaries (Laferrière et al., 2016). Perreault and Laferrière (2017) had recently input the keywords extracted from Quebec provincial curriculum guidelines into the tool so that words used in students' discourses can be compared with those in curriculum expectations.

Meta-discourse level analysis

Meta-discourse level analysis helps plan, monitor and evaluate ideas/themes or threads in community discourse. For instance, Promising Ideas Tool helps students select, aggregate and display ideas which they think deserve the community's subsequent time and efforts and can lead to the most productive direction from the online written discourse by the community members (Chen et al., 2015). In detail, the idea highlighting component helps an individual identify and mark the ideas he/she thinks are promising; the idea aggregation component lists the identified promising ideas and combines the overlapping ones selected by community members from a view; and the ideas export component allows the community to export selected promising ideas to a new view for further development. ITM, a timeline-based collective knowledge-mapping tool, helps users review shared focal themes emerging from interactive discourse, identify knowledge advances, reflect on gaps and problems and address each focal goal over time (Zhang et al., 2015). An idea thread is a conceptual thread of notes aiming to address the same principal issue, extending from the first to the last discourse entry (Zhang, Scardamalia, Lamon, Messina, & Reeve, 2007). A network of idea threads form a whole inquiry initiative. Notes, ideas threads and the network of ideas threads are the three levels that ITM integrates in Knowledge-Building discourse. The KCA is a web-based assessment tool allowing students to reflect on their community knowledge (van Aalst, Mu, & Yang, 2015). Four questions guide this reflection: Are we a community that collaborates? Are we putting our knowledge together? How do ideas develop over time? and What is happening to my stuff? This tool responds to the four questions by querying Knowledge Forum database and analyzing to what extent students' ideas have been read and built-on, the percentage of build-on and refer-to links, the percentage of notes that have received a certain level of interaction, keywords introduced, as well as scaffolds used, the notes that have prompted a given type of interaction with specified frequency and the details of each interactions, as well as students' reflections on some questions. A wiki page holds a permanent and group-authorable summary of the discourse in Knowledge Forum to help students maintain a meta-level summary of their collaborative progress (Hewitt & Woodruff, 2010).

Focus of the assessment tools and teachers' role in using them

Metacognitive Aspects

Some studies focus on investigating how student involvement in planning, monitoring, and evaluation with the help of metadiscourse tools influences their knowledge building. For instance, Chen et al. (2015) explored the extent to which Grade 3 students could make promisingness judgments to facilitate knowledge-building discourse with the Promising Ideas Tool embedded in Knowledge Forum. Students in the experimental group used the tool while students in the comparison group did not have access to it. Both the experimental and comparison classes studied "soil in the environment" for approximately eight weeks. The teacher who taught the comparison had three-year experience with Knowledge Building and Knowledge Forum, while the teacher who taught the experimental group was new to both. The two teachers adopted similar class design, expect that in the experimental group, the teacher engaged the students in the discussion of promisingness and the use of the tool. The results indicated that with the tool, Grade 3 students were capable to make promising judgements, and the judgement process along with the discussion based on the judgement helped them achieve significantly greater knowledge advances. In Chen, Zhang, and Lee's (2013) study, 22 Grade 3 students investigated plants over a two-month period with ITM as a tool to foster collaborative reflection and metacognitive conversations. The teacher's role was not elaborated in the study. Preliminary results suggested increase in student awareness of their collective knowledge, including the focal issues to be investigated and idea development achieved by the community over the two-month period.

Given students' lack of metacognitive skills (Pressley & Ghatala, 1990), Yang, van Aalst, Chan and Tian (2016) adopted the KCA to help 20 Grade 11 students with low academic achievement reflect on their community knowledge. The students explored the topic of "Design" in a visual-art course over four to five months. Two questions guided this reflection: Are we a community that collaborates? and Are we putting our

knowledge together? KCA prompt sheets were provided to record students' KCA results and their interpretations of the data, as well as to help them reflect on the data and plan future actions. The teacher had six-year experience with Knowledge Building. He worked as a co-investigator with the researchers in the curriculum, pedagogy and prompt sheet design, and regularly engaged students in knowledge building talk and reflection on their work. The results indicated that the students could carry out reflective assessment using the KCA, and the reflective assessment might help students focus on goals and strategies of knowledge building and facilitate them to sustain and advance knowledge-building discourse. Hewitt and Woodruff (2010) integrated a wiki page that held a permanent and group-authorable summary of the discourse in Knowledge Forum to help students maintain a meta-level collective understanding of their collaborative progress. Preliminary results with students in two graduate level courses suggested promise of the Summary Note page as a representational guidance tool.

Socio-cognitive Aspects

Some researchers explored how to facilitate the socio-cognitive dynamics of knowledge building/creation with the assessment tools. For example, Hong et al. (2015) investigated how to use the Vocabulary Analyzer, the Semantic Overlap Tool and the Social Network Tool to enhance 22 Grade 5/6 students' ability to continually improve ideas with the teacher. The teacher had five-year experience of implementing knowledge building pedagogy and technology. The inquiry on "human body system" lasted for a semester (approximately four months), and in the first half semester (Phase 1), no analytical tools were used and the generated data served as baseline data, while in the second half semester (Phase 2), the three analytical tools were used. In Phase 2, the teacher presented the functions of the three tools to the students, encouraged them to use the tools and raise questions, and supported collective discussion regarding how to use the tools to support community knowledge advancement. The results indicated that the tools were effective in increasing the frequency of keywords used by individuals and shared by the community, suggesting a more discursively connected community, and the tools enhanced students' collective awareness and reflectivity in relation to community knowledge advancement. Results also showed that the analytic tool support led to shift from breadth-oriented knowledge building discourse to depth-oriented one and from problem generation activities to more self-assessment. Resendes et al. (2015) explored Grade 2 students' ability to engage in productive discussion of the state of their knowledge building using group-level feedback visualizations. Two visualization served as feedback tools – Comparative Word Clouds and Epistemic Discourse Moves Tools. Students in the experimental condition additionally reviewed the two visualizations during KB talk time while students in the control group did not. The results favored the experimental group in terms of domain-specific vocabulary, repertoire of discourse moves, scientific understanding, epistemic complexity of ideas and interpersonal connectedness of online discourse. The teacher co-developed the two tools with researchers, asked students to further elaborate and explain their thinking, considered knowledge gap, encouraged students as needed, introduced feedback information from the two tools and discussed the feedback with students.

Some studies focus on analyzing the social aspects of knowledge building using social network analysis. For instance, the Social Network Tool was used in the second half of the semester where 22 Grade 5/6 students participated in knowledge building on "human-body system" (Hong et al., 2015). The students indicated that the tool helped them figure out whom they had connected with or talked to and whom they should connected with to understand their ideas. Zhang, Scardamalia, Reeve and Messina (2009) analyzed the social network patterns (e.g., density, centralization/inequality) that emerged from Grade 4 students' online interactions over three successive school years to evaluate the effectiveness of different group designs for collective responsibility using note-linking contacts (building on, rising above, and referencing one another's notes). Results indicated that compared to fixed small-groups and interacting small-groups with cross-group knowledge sharing design, opportunistic-collaboration design in which small groups formed and disbanded due to emergent goals led to more distributed collaboration and better collective engagement. Chen et al. (2015) analyzed the impact of promisingness judgments on community cohesiveness using social network analysis. They measured the density, the average weighted degree (indicating the cohesiveness of a network) and the average path length (implying how balanced a network is) of the reading, building on and idea highlighting networks in Phase 1, 2 and 3. In Phase 1 (the first two weeks), the students participated in collaborative idea refinement through KB talk as the students in the comparison group did. At the end of Phase 1, the students in the experimental group engaged in discussion of promising ideas, used the Promising Idea Tool to help identify ideas that worth further inquiry and created a new view for the promising ideas. In Phase 2, the students spent three weeks in advancing ideas in the new view and then conducted the second cycle of promisingness judgement. In Phase 3, the students worked on ideas selected in Phase 2 for two weeks. The results indicated that the density and average weighted degree in reading network were higher than that of building-on and idea highlighting networks. Increased intensity and average weighted degree as well as decreased average path length in both reading and building-on networks indicated higher level of collaboration and more symmetric and

balanced social networks from Phase 1 to Phase 2. In the highlighting network, the average weighted degree increased while the average path length did not.

Rather than using social network analysis to display the interactivity between group members, with lines to represent the relational community members (e.g., Chen et al., 2015; Hong et al., 2015; Zhang et al. 2009), Ma et al. (2016) conducted a content-based social network analysis where the network was created by the agents' semantic-social relationships (e.g., shared ideas via co-occurrence of words in discourse units). Using KBDeX, they analyzed leadership turns over time in an elementary school class and examined the discourse moves associated with temporary leadership. Their results indicated that 20 out of 22 students led the group at different time, and they connected unique ideas to the larger group discussion when they were leading.

Conclusions and Implications

In this study, we reviewed assessment tools that had been developed to analyze knowledge building discourse and empirical studies in which these tools were adopted. Overall, the tools could be categorized into activity monitoring tools, social network tools, discourse level analysis and meta-discourse level analysis. Most of the tools focused on analyzing both individual and community level discourse. Further, empirical studies showed the effectiveness of the assessment tools on facilitating progressive discourse and idea improvement. In the studies, teachers played critical roles by co-investigating the technical and pedagogical designs to nurture progressive knowledge building discourse.

However, existing research focuses mainly on the meta-cognitive and socio-cognitive aspects of knowledge building processes. The emotional aspect of Knowledge Building is rarely explored although the emotional, cognitive and social aspects of collaborative learning interact with each other (e.g., Mullins, Deiglmayr, & Spad, 2013; Zembylas, 2005). In addition, usually several tools were adopted in a study to assess the community knowledge and interactions from multiple perspectives. For instance, the activity monitoring and social network analysis frequently came along with discourse and meta-discourse level analysis, indicating teachers and students might need more integrative and informative assessment tools. Finally, since in the studies, the teachers collaborated with researchers and might seek help when using the tools, teachers' and students' capacity to independently adopt the tools and interpret the results is not clear. This study implies that we need to explore more holistic approach to study the reciprocal relationships between the emotional, cognitive, and social dynamics of Knowledge Building, to design more integrative assessment tools, to study how to make the tools easier to use and to interpret, and to make embedded assessment a norm of knowledge building.

References

Kim, M. S. (2013). Teachers as learning designers through teachers' design thinking. In *Proceedings of the 10th International Conference on Computer Supported Collaborative Learning* (pp. 493-494). Madison, USA

Bateman, H. V., Goldman, S. R., Newbrough, J. R., & Bransford, J. D. (1998). Students' sense of community in constructivist/collaborative learning environments. In *Proceedings of the twentieth annual meeting of the Cognitive Science Society* (pp. 126-131). Mahwah, NJ: Erlbaum.

Burtis, J. (1998). *Analytic toolkit for knowledge forum.* Centre for Applied Cognitive Science, The Ontario Institute for Studies in Education/University of Toronto.

Chen, B., Scardamalia, M., & Bereiter, C. (2015). Advancing knowledge building discourse through judgments of promising ideas. *International Journal of Computer-Supported Collaborative Learning, 10*(4), 345-366.

Chen, B., & Liu, X. (2016, June). WordWhispers: A Tool for Bootstrapping Vocabulary Development in Knowledge-Building Communities. *Paper presented in the Knowledge Building Summer Institute.* Singapore.

Chen, B., & Zhang, J. (2016). Analytics for knowledge creation: Towards epistemic agency and design-mode thinking. *Journal of Learning Analytics*, 3(2), 139-163.

Chen, M. H., Zhang, J., & Lee, J. (2013). Making collective progress visible for sustained knowledge building. *In Proceedings of the International Conference of Computer-Supported Collaborative Learning: To See the World and a Grain of Sand: Learning Across Levels of Space, Time, and Scale* (pp. 81-88).

Derry, S. J. (1999). A fish called peer learning: Searching for common themes. *Cognitive perspectives on peer learning*, 197-211.

Hong, H.Y., Scardamalia, M., Messina, R., & Teo, C.L. (2015). Fostering sustained idea improvement with principle-based knowledge building analytic tools. *Computers & Education, 89*, 91-102.

Hewitt, J. & Woodruff, E. (2010, August). Bringing coherence to knowledge building discussions. Paper presented at the Knowledge Building/Knowledge Forum Summer Institute of the University of Toronto. Toronto, ON.

Laferrière, T., Hamel, C., Hamel, M.-D., Perreault, C., & Allaire, S. (2016, April). Sustaining innovation in a networked classroom: The contribution of pre-service students. Paper presented at the annual meeting of the American Educational Research Association (AERA), Washington, DC.

Ma, L., Matsuzawa, Y., & Scardamalia, M. (2016). Rotating leadership and collective responsibility in a grade 4 Knowledge Building classroom. *International Journal of Organisational Design and Engineering*, 4(1-2), 54-84.

McMahon, M. (1997, December). Social Constructivism and the World Wide Web - A Paradigm for Learning. *Paper presented at the ASCILITE conference*. Perth, Australia.

Mullins, D., Deiglmayr, A., & Spada, H. (2013). Motivation and emotion in shaping knowledge co-construction. *Affective learning together: Social and emotional dimensions of collaborative learning*, 139-161.

Oshima, J., Oshima, R., & Matsuzawa, Y. (2012). Knowledge Building Discourse Explorer: a social network analysis application for knowledge building discourse. *Educational technology research and development*, *60*(5), 903-921.

Perreault, C., & Laferriere, T. (2017, June). Curriculum-based lexical analysis for informing pedagogical decision-making, scaffolding and assessment processes. *Poster presented at the 2017 Knowledge Building Summer Institute*. Philadelphia, USA.

Philip, D. N. (2009). Networks and the spread of ideas in Knowledge Building environments (Doctoral dissertation, University of Toronto).

Popper, K. R. (1972). *Objective knowledge: An evolutionary approach*. Oxford: Clarendon Press.

Pressley, M., & Ghatala, E. S. (1990). Self-regulated learning: Monitoring learning from text. Educational Psychologist, 25(1), 19–33.

Resendes, M., Scardamalia, M., Bereiter, C., Chen, B., & Halewood, C. (2015). Group-level formative feedback and metadiscourse. *International Journal of Computer-Supported Collaborative Learning*, *10*(3), 309-336.

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. *Liberal education in a knowledge society*, *97*, 67-98.

Scardamalia, M. (2004). CSILE/Knowledge forum®. *Education and technology: An encyclopedia*, 183-192.

Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *Journal of the Learning Sciences, 3* (3), 265-283.

Scardamalia, M., & Bereiter, C. (2014). Knowledge building and knowledge creation: Theory, pedagogy, and technology. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (2nd ed.), pp. 397-417. New York: Cambridge University Press.

Stahl, G. (2015). The group as paradigmatic unit of analysis: The contested relationship of CSCL to the learning sciences. In M. A. Evans, M. J. Packer, and R. K. Sawyer (Eds.), *Reflections on the Learning Sciences*. Cambridge, UK: Cambridge University Press.

van Aalst, J., & Chan, C. K. (2007). Student-directed assessment of knowledge building using electronic portfolios. *The Journal of the Learning Sciences*, *16*(2), 175-220.

van Aalst, J., Mu, J., & Yang, Y. (2015). Formative assessment of computer-supported collaborative learning and knowledge building. *Measuring and Visualizing Learning in the Information-Rich Classroom*, 154-166.

Woolfolk, A., Winne, P. H., & Perry, N. E. (Eds.). (2009). *Educational psychology, fourth Canadian edition*. Toronto, ON: Allyn and Bacon.

Yang, Y., van Aalst, J., Chan, C. K., & Tian, W. (2016). Reflective assessment in knowledge building by students with low academic achievement. *International Journal of Computer-Supported Collaborative Learning, 11*(3), 281-311.

Zembylas, M. (2005). Three perspectives on linking the cognitive and the emotional in science learning: Conceptual change, socio-constructivism and poststructuralism. *Studies in Science Education, 41*, 91-116.

Zhang, J., Scardamalia, M., Lamon, M., Messina, R., & Reeve, R. (2007). Socio-cognitive dynamics of knowledge building in the work of 9-and 10-year-olds. *Educational Technology Research and Development*, 55(2), 117–145.

Zhang, J., Scardamalia, M., Reeve, R., & Messina, R. (2009). Designs for collective cognitive responsibility in knowledge-building communities. *The Journal of the Learning Sciences*, *18*(1), 7-44.

Zhang, J., Hong, H. Y., Scardamalia, M., Teo, C. L., & Morley, E. A. (2011). Sustaining knowledge building as a principle-based innovation at an elementary school. *The Journal of the learning sciences*, *20*(2), 262-307.

Zhang, J., Tao, D., Sun, Y., Chen, M. H., Peebles, B., & Naqvi, S. (2015). Metadiscourse on collective knowledge progress to inform sustained knowledge-building discourse. In Annual Meeting of American Educational Research Association, Chicago, IL.