

Principle-Based Design to Foster Adaptive Use of Technology for Building Community Knowledge

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Abstract. Principle-based pedagogical and technological designs were used to support knowledge building in a grade 5-6 class. Pedagogical designs focused on collective responsibility for knowledge advancement. Technological designs focused on provision of a public space for generating and continually improving ideas with (a) social-network-analysis tools to analyze and support community processes, and (b) vocabulary-analyzer and semantic-analysis tools to analyze and support conceptual growth. The tools were used by teachers, students, and researchers. Multi-level content analyses revealed patterns of reflective and adaptive use of the technology to support sustained knowledge building.

Knowledge building is a social process with focus on the production and continual improvement of ideas of value to a community (Scardamalia & Bereiter, 2003). Principle-based design implies theoretically guided design work, to be contrasted with classroom work defined by pre-specified procedures, clear scripts and rules, or componential tasks (see, e.g., Dick & Carey, 1990; Gagne, Wagers & Briggs, 1992; Mager, 1975; Merrill, 1983) or any highly-structured, ritualistic learning activities that represent fixed rather than improvable classroom procedures. Knowledge-building principles represent ideals and design challenges that set the stage for the community's work in "design mode" (Bereiter & Scardamalia, 2003), with the principles themselves serving as objects of discourse for continual improvement. All members of the community are encouraged to go "beyond best practice," as is evident in adaptive and opportunistic patterns of interaction with focus on innovation and increasingly effective educational means that unfold as work proceeds (see Hong & Sullivan, 2008, for a theoretical review).

Twelve knowledge building principles inform this work:

Real Ideas, Authentic Problems. Ideas are viewed as conceptual artifacts (Bereiter, 2002) that are as real as things touched and felt. Knowledge problems arise from efforts to understand the world and the ideas of collaborators, leading to problems of understanding that are quite different from textbook problems and puzzles. *Community Knowledge, Collective Responsibility.* Contributions to shared, top-level goals of the organization are prized and rewarded as much as individual achievements. Team members produce ideas of value to others and share responsibility for the overall advancement of knowledge in the community.

Idea Diversity is as essential to knowledge advancement as biodiversity is to the success of an ecosystem.

Improvable Ideas. Participants view all ideas as improvable; they work to improve the quality, coherence, and utility of ideas in their shared knowledge spaces

Epistemic Agency. Participants deal with the full range of knowledge problems (goals, motivation, evaluation, long-range planning, etc.), including knowledge problems normally left to teachers or managers.

Democratizing Knowledge. All participants are contributors to the shared goals of the community and take pride in knowledge advances achieved by the group.

Symmetric Knowledge Advance. Expertise is distributed within and between communities and team members, with knowledge exchange reflecting a to-give-knowledge-is-to-get-knowledge framework for interactions.

Pervasive Knowledge Building. Knowledge building is not confined to particular occasions or subjects but pervades mental life—in and out of school and across contexts.

Constructive Uses Of Authoritative Sources. To know a discipline is to be in touch with its present state and growing edge. This requires understanding of authoritative sources as well as a critical stance toward them.

Knowledge Building Discourse. Community knowledge is refined and transformed through discursive practices that have the advancement of knowledge as their explicit and primary goal.

Concurrent, Embedded, Transformative Assessment. Assessment is used to identify problems as work proceeds, to engage in self-directed assessment that is more fine-tuned and rigorous than external assessment, and to ensure that the community's work will exceed the expectations of external assessors.

Rise Above. Participants work toward more inclusive principles and higher-level formulations of problems to transcend oversimplifications and move beyond current best practices.

These principles (see Scardamalia, 2002) are indicated in italics throughout the text to convey the ways and extent to which a principle-based approach to design underlies this research.

The technology used to support this research is Knowledge Forum—a multimedia community knowledge space (Scardamalia, 2003; 2004). Participants contribute their ideas in the form of notes to “views” (i.e., virtual spaces for collaborative discourse among community members). Participants are able to co-author notes; build-on, reference, and annotate the work of others; set problem fields and keywords for notes; and create “rise-aboves” that bring greater coherence to the contents of the knowledge space. Reading, linking, referencing, editing, rise-above etc. operations are recorded automatically in the database, and can be summarized statistically by means of an Analytic Toolkit (Burtis, 2002). Technology designs—in line with the overarching commitment to continual improvement—allow for opportunistic planning of classroom work that is under guidance of teachers and students (Zhang, Scardamalia, Reeve, & Messina, 2006).

New analytic tools built into Knowledge Forum and based on its log files have been developed to help assess and support knowledge building. In this paper we discuss three of these tools: the Social Network Analysis Tool, the Vocabulary Analyzer, and the Semantic Overlap Tool. The Social Network Analysis Tool represents social dynamics of the community, showing which members of the community are building on to the work of others or, in contrast, are not communicating or are isolated from others. This tool also shows the number of notes an individual contributes and interactions such as building-on, linking, referencing, rising-above and, more generally, efforts to establish an integrated network of ideas. The Vocabulary Analyzer is designed to trace a member’s vocabulary growth and unique vocabulary contributions over time. It also provides indication of individual and community knowledge advances based on vocabulary level, using various dictionaries or discipline-based resources as benchmarks. The Semantic Overlap Tool is designed to compare key terms extracted from any two sets of notes or texts and to identify overlapping words in those two sets of notes or texts. Thus overlap between terms entered early or late into the knowledge spaces or between student notes and discipline-based or curricular resources can easily be determined. The technology design challenge related to these tools is to continually improve Knowledge Forum as a knowledge-building environment and, in turn, to support users in continually improving their knowledge building practices. The pedagogical challenge is related to the many questions surrounding how such tools can be effectively integrated into the classroom. Issues include: To what extent can tools be integrated into student work in ways that foster rather than defeat knowledge building? Can these tools help with both formative and summative assessment? Is it possible to identify patterns of use that support increasingly high levels of knowledge advancement? Through principle-based pedagogical and technical designs we begin to address these questions and to identify ways in which they can help transform classroom practices.

Method

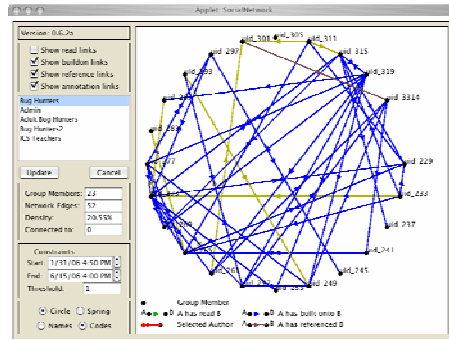
The study was conducted in a science class at the Institute for Child Study, University of Toronto, Canada, in the spring semester, 2006. The students were engaged in a course of study titled “integrated studies” and the theme to be explored was decided by the class—“human body system.” The goal was to gain a deeper understanding, from an interdisciplinary perspective, of the human body as a system composed of many inter-related sub-systems. There were two major initiatives: the internal body as a system, e.g., studying how the brain, nerves, blood and cells work together (this phase covered the first half of the semester); and the physical body as a system, e.g. studying how the head, hands, legs, knees and feet coordinate to enable long jumps (this phase covered the second half of the semester). Through these two initiatives, students studied human body system from both a biological perspective and a physical perspective. Participants were 22 fifth and sixth graders (10 girls and 12 boys) and had been engaged in knowledge building for five or six years depending on their grade level. The teacher was also an experienced knowledge-building practitioner with seven-years of experience with knowledge-building pedagogy and technology.

Research Framework and Procedures. This study employed a within-subject design, with the first inquiry phase and the first week of the second inquiry phase providing baseline data. Analytic tools were introduced between weeks 2-4 of the second inquiry phase, first by demonstrating basic functions to students then encouraging students to use them, but without specific instruction as to how to use the tools. Figure 1 illustrates each tool. The students were also encouraged but not required to record reflections regarding use of the tools in a portfolio view (see below).

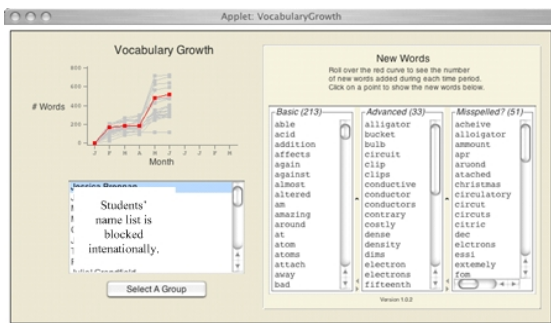
Pedagogical Designs for Tool Use. The purpose of employing a principle-based design was to enable students to advance their knowledge through adaptive and opportunistic use of assessment tools. This is quite different from computer-based assessment in which the student is presented with a result, rather than requesting information, with the evaluator or tool seemingly having greater understanding or control of the work than the student (cf., Conole & Warburton, 2005; Thelwall, 2000).

Knowledge Forum scaffolds are designed to support *epistemic agency*—to give students themselves greater awareness of their performance by giving them means to guide their own knowledge processes. The tools are customizable and allow students to tag information and address matters important to their ongoing work. To facilitate reflective and constructive use of new analytic tools, with emphasis on community knowledge building, the teacher and researchers co-designed scaffolds to be used by students to address the following questions: (1) What information from the tool did you find useful and how will this information affect

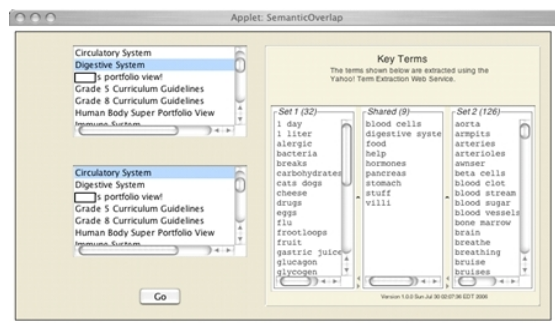
your knowledge building? (2) What is your idea improvement this week? (3) What is your individual plan to advance your knowledge in class next time? (4) How will you contribute knowledge to the class community?



a. Social Network Analysis Tool: social dynamics of a community



b. Vocabulary Analyzer: profile of one person's vocabulary growth



c. Semantic Overlap Tool: shared ideas/key terms between two sets of notes

Figure 1. Three analytic tools in Knowledge Forum used to inform and evaluate community dynamics and conceptual growth.

Data Source and Analysis. The main data source was students' discourse in Knowledge Forum analyzed via multi-level content analyses (Miles & Huberman, 1994, Ch. 5-6) using multiple-grain sizes for "unit of analysis." The goal was to systematically address the following questions, as illustrated in Figure 2: what was being investigated (exploration), how was it investigated (description), and why (explanation)?

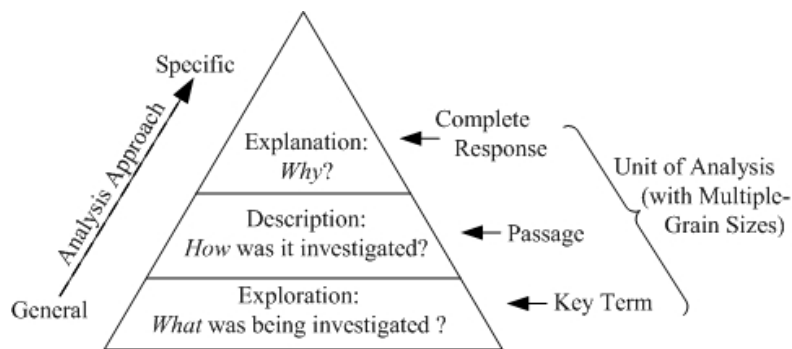


Figure 2. Multi-level content analyses.

The purpose of using multi-level content analyses with multiple-grain sizes for the unit of analysis was to increase the overall validity of analysis (Hogenraad, McKenzie & Peladeau, 2003) and to avoid problems in previous studies showing lack of theoretical coherence and choice of unit of analysis (see de Wever, Schellens, Valcke, van Keer, in press, for a review). The first-order content analysis used key-terms extracted from students' notes for the unit of analysis (see Ch4 in Berelson, 1952; Zolotkova & Teplovs, 2006). First, all key terms within each student's notes in the database were extracted using the Semantic Tool. Then, two researchers read each student's notes and extracted misspelled key terms not picked up by the tool. All automatically and manually extracted key terms formed the key-term set. Two researchers, both with science teaching background

and knowledge of the database content independently analyzed this set of key terms and removed those unrelated to the field of inquiry (i.e. unrelated to biological concepts in phase 1—e.g., cells, blood—and physical concepts in phase 2—e.g., momentum and kinetic energy). Thirty irrelevant key terms were removed from further analysis. Inter-rater agreement was 0.95, differences resolved by discussion.

Key terms and keywords are frequently used to produce subject indices for articles or books or to facilitate search. They are also used for knowledge representation (e.g., tag clouds, see Hassan-Montero & Herrero-Solana, 2006; semantic or propositional representations, see Anderson, 2000; and knowledge or concept maps, see Novak, 1998). Figure 3 shows how key terms can represent community knowledge in students' knowledge spaces. In the oval to the left, overlapping that on the right, there are six key terms (cells, bones, nerves, blood, gene, DNA) These convey the full scope of student A's key-term contributions. The frequency of use of each of the six key terms (nine times) represents the intensity of key-term use by student A. Four of the six key terms are in the middle or shared area, overlapping terms used by student B. The frequency of use of these four shared key-term contributions for Students A and B is 16. Thus the intensity of key-term use in the shared space is 16. To illustrate interactions between Student A's unique and shared contributions, contributions to the shared space are represented as a percentage of the total number of key-term contributions (four out of six or 66.7%) and as a percentage of total instances (16 times over 9 times, which is 1.78). T-tests were used to compare unique and shared contributions in phases one and two of the work reported in the study. The knowledge building principle *idea diversity* can be seen in the full set of unique and shared terms, and *symmetric knowledge advances* in changes over time.

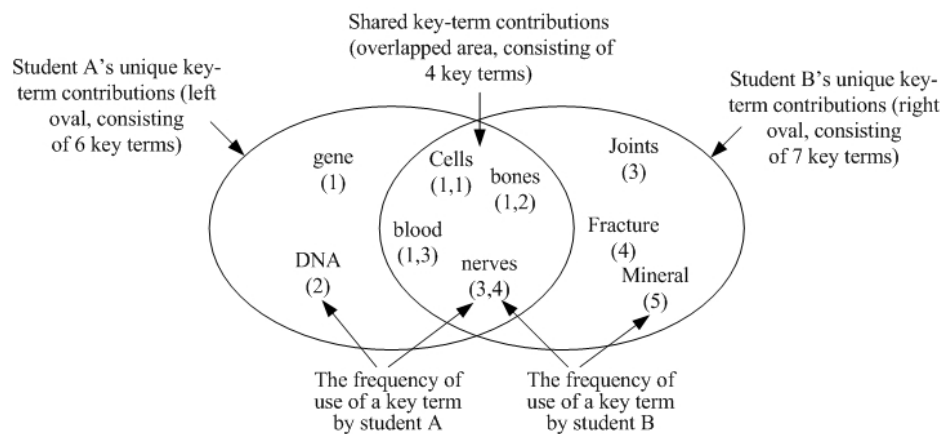


Figure 3. An example of use of key terms for knowledge representation.

The second-order content analysis used passages from students' notes, with the unit of analysis focused on a descriptive analysis of student *collective responsibility for community knowledge* and *epistemic agency*. For this analysis, an open-coding method related to grounded theory (Strauss & Corbin, 1990, chapter 5) was adopted. Two researchers independently coded student notes (inter-rater agreement = .84; differences resolved by discussion). Eight themes, emerged from the open coding, and were then combined into three general aspects of knowledge building: (1) self-initiated questioning and theorizing (including question- and hypothesis-generation and theorizing); (2) self-directed knowledge-advancing activities (including designing or conducting experiments, providing or gathering evidence, finding references or solutions to questions, and planning and monitoring ongoing processes); and (3) self-assessment (including reflecting on what was learned, on what remains to be learned, and on how to advance understanding). These measures most directly tapped the following knowledge building principles, respectively: *real ideas*, *authentic problems* involving *constructive use of authoritative resources*; *improvable ideas*; and *rise above*. The quantified qualitative results were then further analyzed statically (Chi, 1997), by means of repeated measures, to determine if there were significant differences between the two phases of the reported study.

The third-order content analysis used students' responses to questions (identified with scaffolds, as described above) as a unit of analysis to assess *rise above* and metacognitive components of their work. The evaluation of each response was based on the method suggested by Rourke and Anderson (2004) that highlights the importance of developing a theoretically valid protocol. In this particular analysis, the knowledge building principle of *rise above* and Brown et al.'s (Brown, Bransford, Ferrara, & Campione, 1983) conceptual definition of metacognition provided the theoretical basis, along with the overall intent of "*concurrent, embedded, and transformative assessment*." Using the protocol, two researchers independently evaluated all responses and then put them into three pre-defined categories (yes, no, not applicable). Descriptive statistics were applied to calculate percentage for each category. Inter-rater agreement was calculated to be 0.91. Differences resolved by discussion.

Results and Discussion

Key-term use

The students' knowledge spaces were analyzed to identify the personal conceptual content. In terms of the mean number of key terms each student contributed, no significant difference was observed between the two phases ($t=2.065$, $df=21$, $P>.05$). On average, each student generated 40.10 key terms ($SD=17.74$) in phase 1 and 33.27 key terms ($SD=11.35$) in phase 2. However, in terms of the mean frequency of key-term use by each student, there was a significant difference between the two phases ($t=-2.483$, $df=21$, $P<.05$), with mean frequency of key-term use 78.41 ($SD=38.74$) in phase 1 and 100.14 ($SD=40.11$) in phase 2.

In terms of the mean number of key terms shared in the community knowledge space, there was no significant difference between the two phases ($t=-0.617$, $df=21$, $P>.05$; with $M=29.10$, $SD=12.55$, in phase 1 and $M=20.64$, $SD=9.35$, in phase 2). However, in terms of the mean frequency of use of shared key terms in the community knowledge space, there was a significant difference between the two phases ($t=-7.686$, $df=21$, $P<.001$), with the second phase ($M=324.36$, $SD=68.0$) having a higher value than the first phase ($M=203.77$, $SD=63.77$), suggesting advances toward *democratizing knowledge* and, in turn, more *pervasive knowledge building* across phases and contexts. The findings suggest designs had a positive impact on guiding students to pursue more integrative, depth-oriented knowledge building in phase 2. Table 1 summarizes the results.

Analyses comparing the two phases in terms of individual unique contributions to the community knowledge space and impact of the community knowledge space on individual development (e.g., *symmetric knowledge advances*) were conducted. Results showed a significant difference between the two phases ($t=-6.207$, $df=21$, $P<.001$): the mean percentage in phase 2 ($M=93.3\%$, $SD=6.0\%$) is higher than that in phase 1 ($M=73.2\%$, $SD=12.5\%$). This suggests that students contributed more key terms to the community knowledge space in phase 2. In terms of the latter, the results also showed a marginally significant difference between the two phases ($t=-1.976$, $df=21$, $P<.10$) in that phase 2 has a higher ratio ($M=3.68$, $SD=1.41$) than phase 1 ($M=2.97$, $SD=1.05$). This indicates that shared key terms are more likely to be repeatedly used (e.g., elaborated or referred to) in the community knowledge space in phase 2. Table 2 summarizes the results. Overall, this finding indicates more frequent revisiting (e.g., working on, building on, referencing, etc) of key concepts/ideas. These patterns suggest that students were engaged in increasingly effective *knowledge building discourse* as their work proceeded.

Table 1: Comparisons of key-term use between Phase 1 and Phase 2 (N=22).

Key-term contributions	Phase 1		Phase 2		t values
	M	SD	M	SD	
Unique key-term contributions					
Number of unique key-terms	40.10	16.74	33.27	11.35	2.065
Frequency of use of unique key-terms	78.41	38.74	100.14	40.11	-2.483*
Shared key-term contributions					
Number of shared key-terms	29.1	12.55	30.64	9.35	-0.617
Frequency of use of shared key-terms	203.77	63.77	324.36	68.02	-7.686***

* $p<.05$ *** $p<.001$

Table 2. Comparisons: *idea diversity* and *symmetric knowledge advances* between Phase 1 and Phase 2 (N=22)

Ratio of shared key-term use over unique key-term use	Phase 1		Phase 2		t values
	M	SD	M	SD	
Number of shared key-terms divided by number of unique key-terms	73.2%	12.5%	93.3%	6.0%	-6.207***
Frequency of use of shared key-terms divided by frequency of use of unique key-terms	2.97	1.05	3.68	1.41	-1.976*

* $p<.10$ *** $p<.001$

Overall, findings regarding key-term use revealed that students used sophisticated biological and physical concepts throughout their work, as reflected in key terms extracted--cell, blood cell, white cell, B-cell, beta cell, T-cell, embryonic stem cell, etc.--in phase 1; and friction, kinetic energy, linear, acute angle, degree, momentum in phase 2. One student commented, after using the Semantic Overlap Tool to compare his key terms with Grade 6 curriculum guideline, "What I learned from the [Semantic] tool is that I have written some really sophisticated words but the curriculum doesn't have it" (by JW).

Using key terms to represent knowledge has its limitations. One potential limitation may be related to deficiencies in capturing process-oriented community knowledge. Ryle (1949) argues that “knowing-that” and “knowing-how” are two essential kinds of knowledge. Corresponding to the concept of community knowledge, knowing-that may refer to the key ideas, concepts or problems collectively used or explored by the community. Knowing-how may refer to the process through which members arrive at deeper understanding of these ideas. As long as these ideas are recorded in a community database, key terms are a useful tool in representing them. However, they may not be useful in capturing process-oriented knowledge, e.g., how certain key concepts are actually deepened over time in a community. More importantly, knowledge representation by key terms does not capture “promising” ideas. Experts possess a strong sense of what is promising (or problematic) at the cutting edge of their expertise—a form of creative expertise that might well extend their work and is evident in refinements or re-designs that better address problems. To supplement these deficiencies, more in-depth content analyses were conducted.

Collective responsibility for community knowledge and epistemic agency.

Content analyses explored how students assume increasingly high levels of *collective responsibility for community knowledge* and *epistemic agency*. To start it was found there were no significant difference between the two phases in terms of students’ overall knowledge building process, as indicated by the total number of passages coded ($t=.662$, $df=21$, $P>.05$; with $M=13.55$, $SD=6.221$ in phase 1, and $M=11.64$, $SD=4.63$ in phase 2). Supporting data (weekly videotaped classroom observations) confirmed that students were motivated and diligent in pursuit of their knowledge works in both phases.

However, when looking in detail at the three general aspects of knowledge-building—i.e., self-initiated questioning and theorizing, self-directed knowledge-advancing activities, and self-assessment—a repeated measures test indicated that there is an overall significant difference between the two phases (Wilk’s $\lambda = 0.22$, $F=22.51$, $p = .000$, $\eta^2=.78$). Specifically, it was found that there were significant differences in self-initiated questioning and theorizing and in self-assessment. In terms of self-initiated questioning and theorizing, it was found that there were significantly more problems and hypotheses generated in phase 1 ($F(1,21)=34.13$, $P=.000$; $M=13.55$, $\eta^2=.62$) than in phase 2 ($M=11.64$); in terms of self-assessment, it was found that there were significantly more frequent assessment activities occurred in phase 2 ($F(1,21)=17.60$, $p=.000$; $M=5.00$, $\eta^2=.46$) than in phase 1 ($M=1.232$). One thing to note is that the tools can be used to analyze any activity occurring in the database. So tool support not only enabled students to reflect on their inquiry in phase 2 but, as suggested by the following after-the-fact reflection on phase 1, to consider change over time. For example, after using the Social Network Analysis tool, a student wrote the following note, “I have figured out that in the old view people have read each others notes more times but I haven’t connected with one person as many times as the new view.”

Tool-use seems to have changed the dynamics of knowledge building from problem-generation (breadth of inquiry) in phase 1 to greater depth, reflectivity, and self-assessment in phase 2. Results in Table 3 show three aspects of knowledge-building that support this interpretation.

Table 3: Shift in knowledge-building dynamics between Phase 1 and Phase 2 (N=22)

Knowledge-building dynamics	Phase 1		Phase 2		F Values	η^2
	Mean	SD	Mean	SD		
Self-initiated questioning and theorizing	8.09	4.01	3.09	2.22	4.713***	0.62
Self-directed knowledge-advancing activities	4.23	2.49	3.55	2.13	1.024	0.00
Self-assessment	1.23	1.66	5.00	3.10	-4.763***	0.46

*** $p<.001$

Rise above and metacognitive work supported by use of analytic tools

The third-order content analysis investigated the relationship between the changing nature of the knowledge-building dynamics and students’ reflection with tool use. This particular analysis was conducted for phase 2 only as tools were not available in phase 1. This was done by analyzing students’ responses to the four questions built into scaffold designs. The total number of reflections recorded in students’ notes, using scaffolds as described above to capture this activity, was 143 ($M=6.5$; $SD=2.81$). However, students did not always record their thoughts after using the tools, so the actual reflective activity was likely higher than indicated. Table 4 shows the descriptive statistics, using a pre-determined protocol (cf. Brown, Bransford, Ferrara, & Campione, 1983) as evaluative criteria. First, 92.3% of the responses clearly indicated students’ awareness that the tools provided useful feedback to their work. Students mentioned that they (1) became aware of the level of their use of advanced vocabulary (e.g., “The vocabulary [tool]...is good because you can see what you have typed that is advanced and misspelled!” Example 1, by AW), (2) became aware of opportunistic collaborations (e.g., “I really like the network tool. i really enjoy finding out who i have connected with or talked to and who i should talk to

more, to find out their theories.” Example 2, by AW), and (3) became aware of how the key terms used in their notes overlapped with those of others’ (e.g., “...the [Semantic] tool can be helpful if you what to know how many words that you and some one else shared.” Example 3, by GW) and with those covered (or not covered) by the curriculum guideline (e.g., “What I learned from the [Semantic Overlap] tool is that I have written some really sophisticated words but the curriculum doesn't have it.” (Example 4, by JW). Together, the data also showed that there was a strong sense of community facilitated by use of the Social Network Analysis Tool and the Semantic Overlap Tool (see above Examples 2-3).

Second, it was found 90.7% of responses clearly demonstrated that students were able to constructively evaluate their knowledge work for further idea improvement (e.g., “I figured out that putting your legs forward and swinging your body over your legs help a lot.” Example 5, by JF). Moreover, some of these responses demonstrated that students were able to monitor other students’ knowledge progress by contrasting each other’s ideas (e.g., “My idea for improvement early this week was: PUSH KNEES TO 45 DEGREE ANGLE. I tested it out and it really didn't work, although with M.C., who's long jump I have studied many times, it worked perfectly.” Example 6, by AH).

Third, 98.3% of responses demonstrated that students identified and conducted feasible plans to advance their own knowledge relevant to the long-jump work that they were engaged in (e.g., “I am going to get more interested other people's theory.” Example 7, by GD; “[S]ince my [previous] idea worked i will swing my arms up next time and tuck [myself] into a ball in the air.” Examples 8, by PJ; “My new plans are to try to get more height. And when i did my jump i will try to keep my legs together for the whole jump. Cause on my jump i put my legs together for just the end. And not the whole jump so i don’t know if it is better or not.” Example 9, by CW).

Finally, it was found that 96.6% of responses demonstrated that students were able to generate and conduct feasible plans for the purpose of advancing community knowledge (e.g., “My plan to give knowledge to the class is first i'm going to look at my data from my third jump. Then i'm going to write about it in Knowledge Form so people won't have to try it again because I tried it.” Example 10, by JW; “I will share this information by showing how far i got when i swung my arms up and then i will show how far i got when i tucked into a ball and swung my arms.” Example 11, by PJ).

Tool use seems related to students’ awareness (see, Examples 2-3) and actions (see, Example 7) in relation to community knowledge building. However, our design does not allow us to identify causal relationships and there was no control group, so there is no way to determine to what extent students’ enhanced performance was due to experience rather than tool use. Nonetheless, students in the present study have approximately 5 years of knowledge building experience and the issue was whether their experience could be extended beyond previously demonstrated capabilities. Findings suggest extension of socio-metacognitive capacity by allowing students to *rise above*—to reach a higher vantage point for the achievement of collective goals. For example, they were better able to reflect on their role in relation to others through use of the Social Network Tool and on their contributions in relation to idea generation and refinement by themselves and others through use of the Vocabulary Analyzer and Semantic Overlap Tool.

Table 4: Number of reflective responses and percent effective implementation for knowledge-building (N=143).

Reflective Practice (Questions--Q 1-4--respectively)	Number of Reflective Responses	Percent Effective Implementation
Awareness (Q1)	26	92.3%
Evaluating/Monitoring (Q2)	43	90.7%
Planning--enhancing personal knowledge (Q3)	39	98.3%
Planning--contributing to community knowledge (Q4)	30	96.6%

Note: Number = the total number of reflective response in each “reflective practice” category; percentage = the percent of responses demonstrating effective tool use to support knowledge building.

Summary and Conclusions

Principle-based designs to foster adaptive use of technology for building community knowledge enabled pursuit of community knowledge as reflected in (1) increasingly focused and sustained key-term use for the community as a whole and, in parallel, increases in individual contributions (key terms) to the community; (2) increases in reflective activity; and (3) self-direction of work reflected in sophisticated tool use. Overall, the principle-based approach provided a flexible design framework to inform community progress, not simply individual knowledge work.

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