Ways of contributing to a dialogue in science

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Abstract

The proposed research is a small study that will form part of a larger program broadly addressing new ways that education can strengthen a society's capacity to produce new knowledge. The focus of the research is on elementary school students' emergent ways of contributing to knowledge-building discourse. Based on the procedures of "Grounded Theory" (Glaser & Strauss, 1967), we develop an empirically grounded list of ways of contributing to a dialogue in science and examine how these ways frame a knowledge-building classroom. Six major contribution types represent the center of our analyses: asking thought-provoking questions, theorizing, experimenting, working with evidence, creating syntheses and analogies and, finally, supporting discussion. More precisely, we examine which ways of contributing are the most popular in a knowledge-building classroom, which ways students seldom or never use and that may accordingly be the objects of subsequent instructional intervention, what is the role of a teacher in developing distinctive contribution types in students and, finally, how various contributions support each other in a dialogue. Several recommendations are suggested for enhancing effective knowledge-building discourse.

Introduction

Knowledge creation and innovation have risen to high prominence in both the economic sphere (David & Foray, 2003) and the sphere of societal problem solving (Homer-Dixon, 2006). This paper is concerned with the role education might play in increasing society's capacity for knowledge creation (Bereiter & Scardamalia, 2006; Carnevale & Desrochers, 2003: Scardamalia & Bereiter, 2007). Among educational approaches that can claim special relevance in this respect (e.g., project and problem-based learning, "21st Century Skills" programs), "knowledge building" stands out as most directly addressing the need for knowledge-creating talent. Defined as "the deliberate creation and improvement of knowledge that has value for a community" (Scardamalia & Bereiter, 2003), knowledge building is synonymous with knowledge creation. The terms may be used interchangeably, but "knowledge building" is more common in educational contexts. Knowledge building makes students' collective efforts to advance the frontiers of knowledge (as they perceive them) the main driver of the educational process. Thus, it challenges students to be not only learners but active contributors to group efforts to produce and continually improve "epistemic artifacts"—explanations, problem formulations, proofs, experimental methods, histories, "state of the art" reviews, and the like.

The proposed research is a small study that will form part of a larger program broadly addressing new ways that education can strengthen a society's capacity to produce new knowledge. A guiding idea is that students should learn knowledge creation by doing it—doing it as part of their core academic work, not as a sideline. The focus of this research is on elementary school students' emergent ways of contributing to knowledge-building discourse. Questions guiding the research are as follows: Which ways of contributing characterize a knowledge-building classroom? Are there any potentially valuable ways of contributing that students seldom or never use and that may accordingly be the objects of subsequent instructional intervention? Are there any students who manifest habitual and distinctive ways of contributing? Which ways of contributing characterize a knowledge-building teacher? Is there a relationship between various ways of contributing to a dialogue in science? If so, how do they support each other?

Research bearing on the role of the individual in collaborative knowledge building includes the study by Lee, Chan and van Aalst, (2006), in which students documented their contributions in relation to five principles: "working at the cutting edge," "progressive problem solving," "collaborative effort," "monitoring own knowledge," and "constructive uses of resources." With his popular "six thinking hats," de Bono (1985) identified 6 thinking strategies applicable to knowledge creation, which could also be construed as distinct ways of contributing: facts, emotions, negative judgment, positive judgment, alternatives and creativity, and finally, process control. Leng, Lai, and Law (2008) elaborated a taxonomy of ways of contributing on the basis of levels of cognitive complexity. All these are *a priori* types. Hogan (1999), observing student interactions in science discourse, identified 8 naturally occurring roles, 4 of which involved positive contributions similar to 4 of de Bono's "six hats": promoter of reflection, contributor of content, creative model builder, and mediator of group interactions and ideas. We intended to develop an empirically grounded list of ways of contributing that would be finer grain than the above and to examine which ways of contributing are essential to a knowledge-building dialogue in science.

At the Institute of Child Study (ICS)—an elementary school site chosen for this research—"knowledge-building discourse" is integral to the day-to-day workings of the class. Students reference, evaluate, build on, and work to continually improve ideas—their own and those of community members. The quality of knowledge-building discourse is increased through giving students greater collective responsibility for advancing ideas (Zhang, Scardamalia, Lamon, Messina and Reeve, 2007). In addition to face-to-face discussions, students at ICS work in an online environment—Knowledge Forum (Scardamalia, 2002)—that provides a community space for collaborative work with ideas, the stored record of which constitutes data for proposed research. Of particular relevance to this research are the following characteristics of Knowledge Forum: (1) "build-on," reference, linking, and annotation features support interaction; (2) views support graphical as well as textual literacy; (3) "rise-above" notes facilitate the creation of higher-order knowledge structures; (4) "scaffolds" (*i.e.* "My theory is..", "I need to understand..", "New information..") make it easy for users and researchers to identify and tag discourse types; These features enable research of a depth not possible with typical discourse environments, yet findings will be applicable to efforts to improve discourse in other on-line and face-to-face environments.

Zhang et al. (2007) report the evolution of knowledge building practices at ICS over several years with the same teacher and different students studying optics each year. Teacher and students were experienced in knowledge-building pedagogy and technology, so the situation represents what Fischer and Bidell (1997) call "optimal conditions" for identifying cognitive developmental goals. Evolving practices were aimed at improving collective responsibility for knowledge advancement. The proposed study uses the same data set but focuses on individual ways of contributing to the collective discourse, to complement group-level variables studied by Zhang, et al. (2007). We will explore each of the students' patterns of engagement, contributions that impede or enhance community discourse. We will also study how a teacher influences the way that students contribute and how different contribution types support each other.

Method

Participants and Dataset

As mentioned earlier, this research uses a dataset that has been previously analyzed by Zhang, et al. (2007). The participants were Grade 4 students (11 girls and 11 boys) and their teacher from the Institute of Child Study, University of Toronto. The teacher has been committed to Knowledge Building and used Knowledge Forum for the previous 2 years.

The dataset analyzed in this research covers 4 months of online discourse on optics and includes 6 *views*: "All we see is light" (17 notes), "How light travels?" (67 notes), "Colors of light" (85 notes), "Light and materials" (64 notes), "Natural and artificial light" (57 notes) and "Shadows" (28 notes).

Seventy percent of all notes were students' *personal notes* (written by individual students), 20% were *group notes* (written by small groups of 2-5 students) and 6% were *teacher's notes*. This paper examines only *personal notes*, while *group notes* were excluded from the analyses.

List of Ways of Contributing

On the basis of informal observation and the knowledge creation literature, a provisional list of contribution types was first created. Then, using well-recognized iterative procedures of "Grounded Theory" (Glaser & Strauss, 1967), this list was revised and extended. Six major categories consisting of 20 sub-categories (in total) have been finally identified:

I. Formulating thought-provoking questions:
- 1—explanatory questions
- 2—design questions
- 3—factual questions

II. Theorizing:
- 4—proposing an explanation
- 5—supporting an explanation
- 6—improving an explanation
- 7—seeking an alternative explanation

III. Designing an experiment:
- 8—proposing or describing an experiment,
- 9—identifying a design problem
- 10—thinking of design improvements

IV—Working with evidence:
- 11—asking or looking for evidence
- 12—providing an evidence or reference to support a particular idea
- 13—providing an evidence or reference or to discard a particular idea

14—finding new facts

V—Creating syntheses and analogies
15—synthesizing available ideas
16—creating analogies
17—initiative rise-above entries
VI—Supporting discussion
18—using diagrams to communicate or support ideas
19—giving an opinion
20—acting as a mediator.
(See Appendix A for the Coding Guide with a detailed description of 20 sub-categories and related examples)

Three independent raters used this list to code the notes. When the same note fell into more than one contribution type, all related categories were counted. For example, if in the same note student asked a question (‘*How light travels?*’), proposed a theory to answer this question (‘*My theory is that light travels in a straight line’*) and included a diagram to make this theory visual, then three contribution types were counted: 1—formulating an explanatory question, 4—proposing an explanation, and 18—using diagrams to communicate or support ideas. Three raters agreed in 80% of the coding. The remaining 20% were mutually discussed with a goal to arrive to a final agreement.

Results and Discussion

General overview

> Questions: Which ways of contributing students are the most popular in a knowledge-building classroom? Are there any potentially valuable ways of contributing that students seldom or never use and that may accordingly be the objects of subsequent instructional intervention?

In order to answer these questions, a total number and a percentage of contributions were calculated for each major- and sub-category.

Insert Table 1 about here

As displayed in table 1, the most frequent contribution types were those related to *theorizing* (30.66% of total contributions) and *working with evidence* (21.34%). Thus, during 4 months period, an average KB student contributed about 6 times to theorizing dialogue and about 5 times to evidence-based dialogue. More precisely, the students were more effective in supporting already existing explanations (11.46% of total contributions) than proposing new explanations or improving the old ones (6.98% and 7.25% respectively). Seeking alternative explanations turned out to be the most rarely used aspect of *theorizing* (4.86%). As for evidence-based contributions, students were quite effective in bringing factual knowledge to the discussion. However, most of those facts were not necessarily related to specific theories, but rather interesting and new to students (10.40% of total contributions). Only 7.13% of contributions used evidence or reference to support a particular idea, and 2.86% to discard a particular idea.

In regard to the most rarely used contribution types that could potentially be objects of subsequent instructional intervention, two major categories should be noted: *designing an experiment* (5.27% of total contributions) and *creating syntheses and analogies* (5.74%). More precisely, only 1 *note* was created by an average KB student to contribute to an experiment design, and 1 *note* to syntheses and analogies. Particularly rare were personal *notes* dealing with design improvements (0.09%), rise-above entries (1%) and analogies (1.35%).

Individual profiles

> Questions: Are there any students who manifest habitual and distinctive ways of contributing? Which ways of contributing characterize a knowledge-building teacher?

In order to answer these questions, the total number of contributions per category was calculated for each particular participant. Figure 1 displays the results for 6 major contribution types.

Insert Figure 1 about here

As depicted in figure 1, most of students followed the same contribution pattern: higher values were observed for *theorizing* and *working with evidence*, and lower values for *experimenting* and *creating syntheses and analogies.* Surprisingly, there were no distinctive contribution profiles that would dramatically differ from the general pattern. For instance, we did not find any pronounced "questioner", "theorizer" or "experimentalist". Instead, if students were active in one particular contribution type, they were proficient in other ones as well and vice versa.

One of the possible interpretations would be that students' contributions were pre-determined by the same factor: the teacher. In other terms, the teacher would play a dominant role in a way that students contribute to a scientific dialogue. Indeed, analysis of teacher's notes demonstrated that 26.67% of his contributions were 'explanatory questions' that certainly provoked a high degree of *theorizing* in students; 30% were factual questions encouraging students to look for new facts and 23.33% were questions asking for evidence to support a particular theory. All these questions, without doubt, framed the way that students contributed. On the other hand, the teacher was less efficient in design questions (13.33%), did not contribute to experimenting (0%), synthesizing (0%), rising-above (0%), or analogies (0%). This could explain why these categories were poorly represented in students' personal notes as well.

Finally, it has to be noted that even though the teacher influenced the major direction of contributing (whether it was directed towards theorizing, experimenting, working with evidence etc), he had less impact on how exactly it was expressed. Thus, whereas most students performed a lot of *theorizing*, the exact types of theorizing were different from one student to another. For instance, there were students who excelled in proposing new theories, but failed to improve them; students who have always supported already existing theories, but did not propose alternative ones; and finally, students who were especially proficient in theory improvement.

Correlations

Questions: Is there a relationship between various ways of contributing to a dialogue in science? How different contributions support each other?

In order to examine whether there was a relationship between different contribution types, a Spearman correlation analysis was performed on the total number of contributions. The contribution types that were particularly rare in the class – observed in less than 15% of participants – were excluded from the analyses (notably, formulating design questions, thinking of design improvements and initiating rise-above entries). As shown in Table 2, analysis of results reveled several significant correlations:

Insert Table 2 about here

- Formulating explanatory questions positively correlated with proposing explanations (r = .53, p = .01) as well as synthesizing available ideas (r = .46, p = .03). Thus, the higher the number of explanatory questions formulated by students (*e.g.* "why does it happen?" or "how does it work"), the superior the number of theories they proposed and the number of times they synthesized ideas.

- Formulating factual questions positively correlated with supporting explanations (r = .50, p =.02) and finding new facts (r = .52, p = .01). Therefore, the students who were particularly interested in questions asking "what, who and when?" were also those who provided multiple justifications for theories and found a higher number of new interesting facts to complete available knowledge.

- There was a positive correlation between proposing explanations and creating analogies (r = .46, p = .03). This means that the ability to create new explanations for certain phenomenon is closely related to the ability to perceive this phenomenon through an analogy. Thus, these two contribution types seem to support each other.

- A positive correlation was detected between supporting explanations and providing evidence or references to support an idea (r = .47, p = .03). Such a correlation was not surprising, but rather expected, since theory justification needs an ability to re-examine information from personal experience or authoritative sources, and use it to defend a particular idea.

- Improving a theory positively correlated with two variables: a capacity to provide an evidence or reference to support an idea (r = .60, p = .003) and a capacity to find new interesting facts not necessarily related to particular theories (r = .52, p = .01). Thus, working with evidence seems to play a dominant role in theory improvement: the more students examine the information from authoritative sources or their own experience, the higher the chance for them to improve a theory.

- An ability to provide evidences or references to support ideas was also positively and significantly connected to the following variables: finding new facts (r = .49, p = .02), synthesizing available ideas (r = .53, p = .01), and creating analogies (r = .51, p = .02). Overall, it seems that arguing through evidence and references is essential to the main aspects of scientific dialogue: from *theorizing* to *creating syntheses and analogies*.

- Finally, another significant correlation to be pointed out is the correlation between an ability to synthesize available ideas and to create analogies (r = .49, p = .02), which means that if a student excels in one higher-order thinking process, he/she would most probably excel in another one as well.

Conclusion

The goal of this study was to develop an empirically grounded list of ways of contributing to a dialogue in science and to examine how these ways frame a knowledge-building classroom. Based on the procedures of "Grounded Theory" (Glaser & Strauss, 1967), 6 major contribution types were identified: I—Asking thought-provoking questions, II—Theorizing, III—Experimenting, IV—Working with evidence, V—Creating syntheses and analogies, and finally, VI—Supporting discussion. The analysis of results revealed that the majority of students' contributions were dedicated to *theorizing* and *working with evidence*. This proves that within an appropriate environment even young students are able to propose new explanations to phenomena, support these explanations and improve them. Students are also quite efficient at finding new and interesting facts to enrich the discussion. One of the possible recommendations for teachers would be to help students in further work with evidence, notably to focus on the relations between new interesting facts and available theories. Indeed, as demonstrated by correlational analyses, theory improvement is closely related with an ability to use evidence and reference to support an idea. Thus, the more connections identified between a certain theory and facts, the higher the chance students can work to improve this theory. This finding is also in line with a concept of 'explanatory coherence' reflecting how efficient the theory is in explaining relevant facts (Thagard, 1992, 2007).

Another possible recommendation for teachers would be to pay more attention to *experimenting* and *creating syntheses and analogies*, since these two categories did not find special popularity in students' contributions. Even if students conducted multiple experiments in the classroom, they rarely held online discussions in which they identified design problems or resolved them with the goal of experiment improvement. Of course, it would be unwise to expect grade 4 students to excel in higher-order thinking, such as synthesizing available information or creating rise-above entries, but these processes could without doubt benefit from teacher's modeling. Indeed, as indicated by analyses of individual contributions patterns, the teacher did not create any note that would synthesize available ideas, play with analogies or serve as a rise-above entry. This might be explained by the fact that teacher did not want to take over cognitive responsibility for higher-order processes from students and preferred to ask questions rather than provide solutions. And this is exactly what we expect from a knowledge-building teacher. However, it is possible that students need at least one example of each higher-order process to be able to do it on their own in an online environment. But again, the teacher should be careful with such modeling in order to preserve cognitive responsibility with students. Thus, as always, a "golden balance" is needed.

Finally, it should be noted that different ways of contributing do not represent independent entities, but function as an inter-related system. Thus, our analyses reveled that interest in explanatory questions is closely related to an ability to propose explanations and synthesize ideas. In the same manner, interest in factual questions leads to the search in authoritative sources for new interesting facts that could be later used to support theories. A capacity to generate new explanations is connected to an ability to think through analogies, etc. Therefore, different contribution types should not be examined in isolation from each other, and we would recommend paying equal attention to development of each particular way of contributing.

To conclude, we would like to note that this study represents only a starting point of a larger research program. Certainly further work is needed to clarify what kind of contributions elicit response or "block" discussion, and more importantly, which ways of contributing lead to conceptual breakthroughs in the classroom. We believe that responses to these questions will help educators to increase society's capacity for knowledge creation.

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Table 1

Frequency of occurrence and percentages of contribution types: Means and Standard Deviations

Major category	N		%		Sub-category SD	N		%	
	M	*SD*	*M*	*SD*		*M*	*SD*	*M*	*SD*
Formulating thought-provoking questions	3.73	2.66	17.89	8.14	1—Explanatory questions	2.05	2.19	8.77	7.76
					2—Design questions	.14	.35	0.81	2.09
					3—Factual questions	1.55	1.14	8.31	7.11
Theorizing	6.09	3.05	30.66	8.07	4—Proposing an explanation	1.45	1.30	6.98	5.51
					5—Supporting an explanation	2.18	1.40	11.56	7.15
					6—Improving an explanation	1.55	1.74	7.25	6.63
					7—Seeking an alternative explanation	.91	1.15	4.86	5.95
Designing an experiment	1.05	1.00	5.27	5.06	8—Proposing/describing an experiment	.68	.78	3.42	4.00
					9—Identifying a design problem	.32	.57	1.76	3.15
					10—Thinking of design improvements	.05	.21	0.09	0.44
Working with evidence	4.86	3.93	21.34	10.46	11—Asking or looking for evidence	.23	.53	0.95	2.51
					12—Providing an evidence or reference to support a particular idea	1.55	1.41	7.13	5.33
					13—Providing an evidence or reference to discard a particular idea	.55	.67	2.86	4.04
					14—Finding new facts	2.55	2.67	10.40	8.74
Creating syntheses and analogies	1.18	1.30	5.74	6.19	15—Synthesizing available ideas	.68	.78	3.38	3.60
					16—Creating analogies	.32	.57	1.35	2.55
					17—Initiating a rise-above entry	.18	.50	1.01	2.70

Supporting discussion	3.64	2.61	19.10	13.15	18—Using diagrams to communicate or support ideas	2.64	2.22	13.96	10.02
					19—Giving an opinion	.73	.88	3.93	5.59
					20—Acting as a mediator	.27	.55	1.21	2.49