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Developing a Learner-Centered Classroom Through Collaborative Knowledge Building

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Yezhezi Zhang is a student at Smith College who is pursing a Bachelor Science degree in engineering. Motivated by the importance of education in improving social mobility, she is passionate about engineering education. With a strong interest in learning theories, she has conducted education research with a focus on Knowledge Building theory and the 21st century skills in hopes of designing a more effective learning environment.

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A Smith College sophomore majoring in engineering, Xi has participated in the knowledge building special study group since last semester. She is also the instructional designer in the project designing online engineering learning environment for hight school students. Being active in extracurriculum life, she is the secretary of a student organization working on magazine for smith scientific life and the member of the chamber music group. Xi is from Ningbo, China, plays the piano, loves reading, and is really interested in knowledge building.

Developing a Learner-Centered Classroom Through Collaborative Knowledge Building

The Accreditation Board for Engineering and Technology (ABET) sets a variety of technical and nontechnical student outcomes for engineering programs. Many of the technical outcomes require students to develop deep understanding of content in order to solve real problems in complex situations. The non-technical outcomes include the ability to work creatively with ideas and generate new theories, products, and knowledge; to engage in life-long learning; and to communicate effectively and function on multidisciplinary teams. These non-technical outcomes reflect the growing demand for graduating engineers to develop what are often referred to as 21st-century skills and capabilities.

Among the 21st-century capabilities, the ability to create knowledge in a collaborative community is particularly important for success in the knowledge economy. Knowledge building processes are what scientists, scholars, and employees of highly innovative companies engage in daily. To prepare students to succeed in today's knowledge economy, education should be targeted at engaging students in these processes and developing these capabilities (Sawyer, 2006). Advances in the learning sciences have opened new possibilities for pedagogical innovations in engineering to help students meet both the technical and the non-technical outcomes.

Recent studies in the learning sciences show that learning environments for knowledge creation should be learner-centered, idea-centered, and community-centered (Harris, et al., 2002). One of the theories that arises from these studies is knowledge building (Bereiter, 2002; Scardamalia & Bereiter, 2006; Bereiter & Scardamalia, 2003; and Scardamalia & Bereiter, 2006). In knowledge building a community of learners participates in a sustained discourse to share knowledge, formulate and refine inquiries, and continually improve their collective ideas and understanding of authentic problems. It begins with a question of understanding that is developed by the participants, such as, *Why do we need water to survive?* Learners are encouraged to generate and post their ideas about the topic—typically in an asynchronous, online group workspace such as provided by Knowledge Forum software (Scardamalia, 2004). In the process the community organizes itself into working groups that grow and change in response to the interests of learners. The workspace preserves the discussions so that the learners can return to them for comment and reflection. Through this process students learn how to develop a questioning attitude, become self-directed learners and participate in an interactive discourse. They develop not only a deeper understanding of the content in their discourse, but also 21st-century skills (Scardamalia, 2002). Scardamalia and Bereiter (2003) provide determinants that define knowledge-building discourse, including the following:

- Problems are ones that participants care about.
- Knowledge advancement is the explicit and shared goal of all participants.
- All ideas are treated as improvable.
- Advancing knowledge requires idea diversity; understanding an idea means understanding the ideas to which it is related.
- Participants work toward broader reformulations of the problem.
- Participants negotiate and work toward effective collaboration.
- The participant structure is inclusive, all are empowered, and expertise is distributed among participants.

- The discourse results in more than sharing of knowledge; it also refines and transforms knowledge.
- Assessment is an integral aspect of knowledge work.

Discourse is central to knowledge building. Much research has been conducted to explore designs for knowledge-building discourse communities in elementary and secondary level classrooms. However, the potential for using knowledge building in undergraduate education—and engineering in particular—remains largely unexplored. In order to inform and examine designs for idea-centered, knowledge-building discourse communities in undergraduate engineering education, this paper reports on an analysis of the data collected in a sophomore engineering mechanics course using knowledge-building pedagogy. This includes attempts to measure (1) changes in the learners' conceptualization of the learning process based upon survey data and (2) changes in the nature of their knowledge-building contributions over time based on an analysis of knowledge-building discourse.

Learning Environment

Participants

Data was collected over a two-year period in a four-credit, semester-long introductory engineering mechanics course at Smith College. The participants for the year 2010 were 39 female students. The participants for the year 2011 were 43 female students and one male student. The majority of students were sophomores majoring in engineering science. None of the students had prior experience with knowledge building. The instructor had an in-depth understanding of knowledge building and had prior experience with implementing knowledge building in other engineering courses.

Knowledge building was integrated into the course for the first time in Fall 2011. Students were required to participate for the entire semester and used Knowledge Forum to record their discourse. The contents of labs, homework, and in-class examples of the course in Fall 2011 were all modified from the previous year to support the knowledge-building themes of this course. However, all exams and supporting materials for the class (such as concept maps and example problems) maintained the same topics and depth of mechanics content.

Knowledge Forum Workspace

Knowledge Forum is an online asynchronous environment where users can contribute theories, working models, plans, evidence, data and resources by posting notes to *views* that are accessible to all community members. Both notes and views are multimedia spaces, supporting text, graphics, and videos. Supportive features of Knowledge Forum allow users to build-on, co-author, and annotate notes of community members and to create reference links with citations to other notes. The build-on notes generate arrows pointing to the original notes upon which they build and form growing networks of knowledge-building threads. The users can easily organize views by moving notes into sections, wrapping sections with drawings, and inserting pictures and texts. In addition, the users can also create new views for different topics or purposes. Figure 1 shows the main view for a workspace and Figure 2 shows example notes from early in the semester.

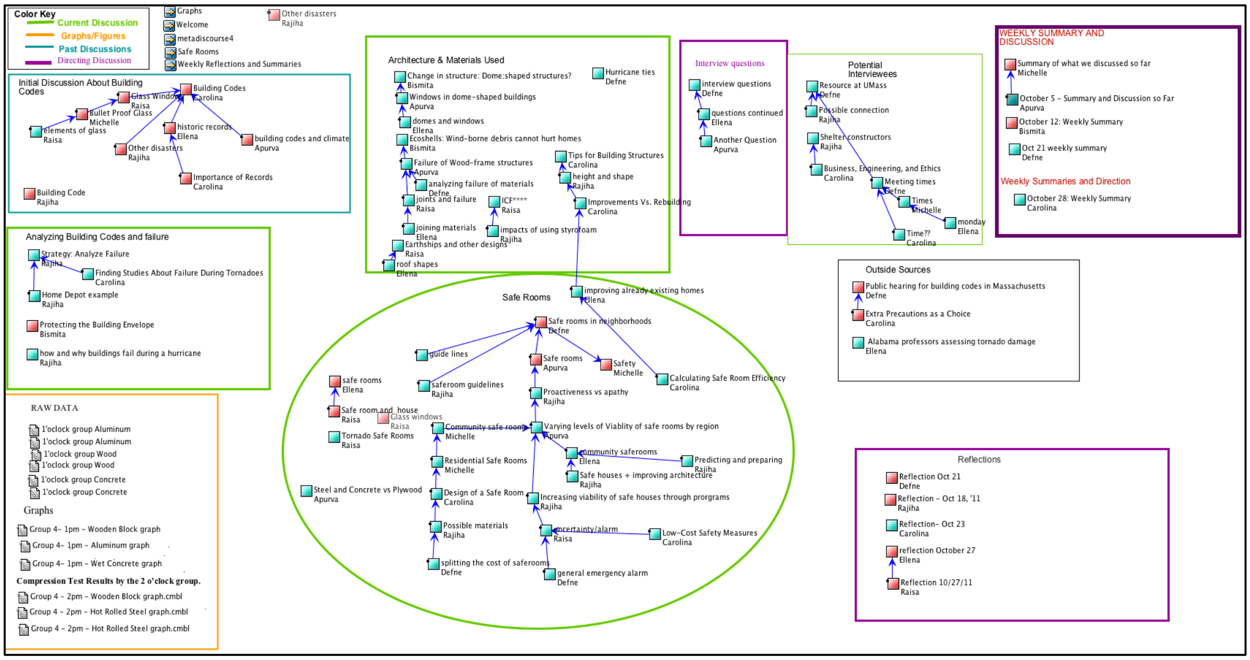

Figure 1: Knowledge Forum main view of Group 4 on 11/7/2011. Unread notes are shown in blue and read notes are shown in red. The workspace also contains links to other views embedded within the main view and data files. Students designed and organized the workspace.

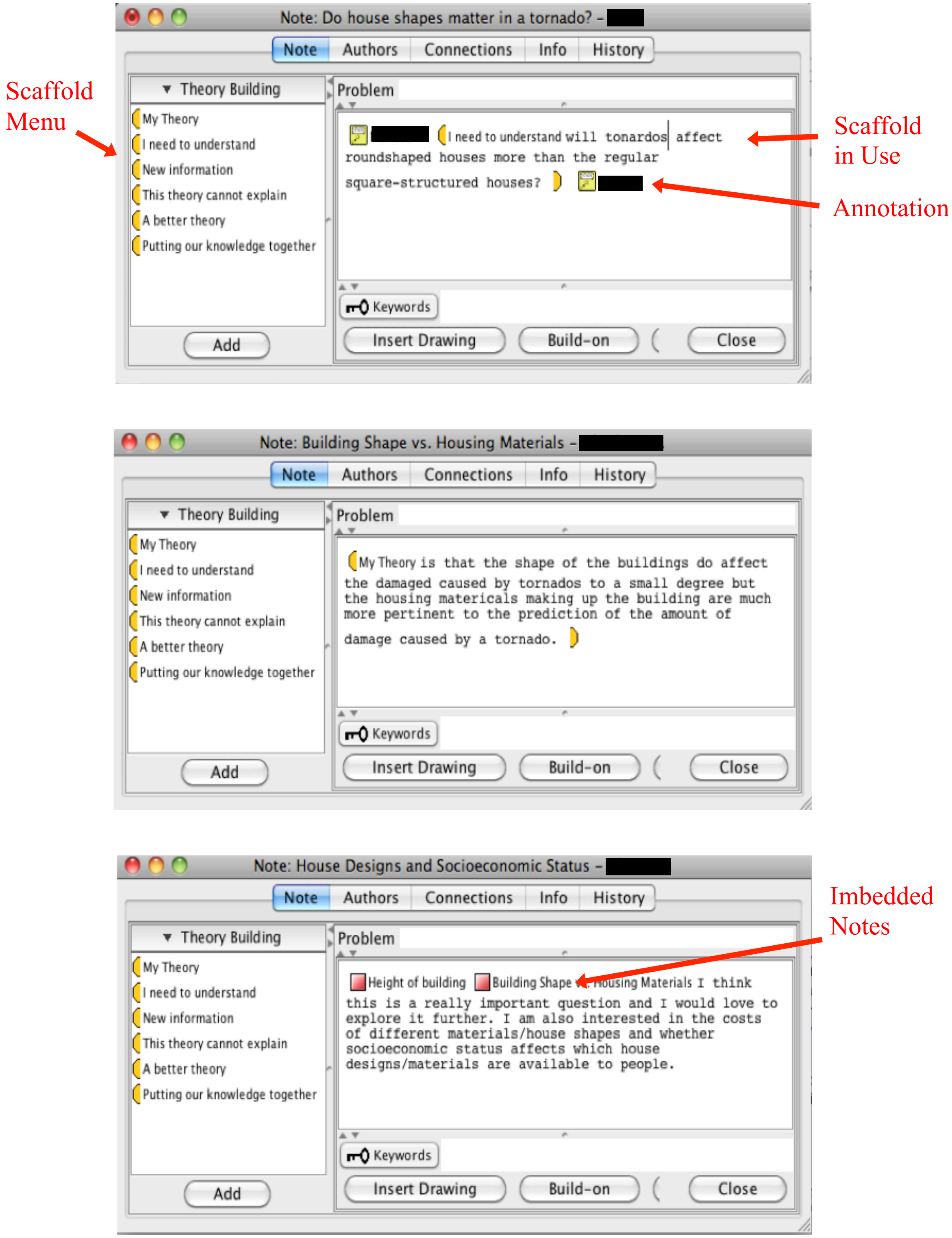

Figure 2: Open notes for three of the posts shown in Figure 1. Some of the features of *Knowledge Forum* are highlighted on the figures showing the use of scaffolds to help students engage in theory improvement (as opposed to just sharing ideas), the use of annotations for classmates to add short comments within a note, and imbedding/linking other notes within a new note. Note: student names have been blacked out for privacy.

The Knowledge Building Classroom in Fall 2011

The knowledge-building component of Engineering Mechanics consisted of both online and face-to-face discourse. Thus, the class may be considered a “hybrid class,” corresponding to the third of four types of class given by Allen and Seaman (2005): blended, hybrid, or web-enhanced classes with both face-to-face and online interaction. There is evidence that hybrid classes may be more successful than other forms of online classes (Palloff & Pratt, 2001). Because of the hybrid nature of knowledge-building classrooms, much of the discourse is face-to-face, in addition to discourse mediated through Knowledge Forum. The students were introduced to the principles of knowledge building through assigned readings, in-class presentations given by the instructor, and discussions with the instructor and a teaching assistant (referred to as KB Talks).

The Context for Knowledge Building Inquiry

An EF-3 tornado struck communities near Springfield in the summer of 2011. Understanding how the tornado impacted buildings became the context for knowledge building in Engineering Mechanics. After a site investigation of several affected neighborhoods and meeting with local residents, students were asked to develop one knowledge-building question within their group (note: in subsequent years students first worked on developing knowledge-building questions and then groups were formed with students having similar interests). Each group then started exploring and developing ideas around their group question, collectively improved their ideas and refined their question as their understanding progressed throughout the semester.

Face-to-Face KB Talks

While most of the KB discourse took place through the online knowledge forum, the groups met bi-weekly with the instructor and the teaching assistant to discuss their progress. The face-to-face KB Talks were specifically designed to boost the collaborative group environment, as well as to sustain and deepen their knowledge-building discourse. Key principles of knowledge building (such as the proper use of authoritative resources and the need for rise-aboves—i.e. moving to higher planes of understanding that transcend trivialities and oversimplifications) were brought into these meetings when it helped the discourse. For example, most students initially would bring in authoritative sources by merely posting a note with the URL of an authoritative source. The instructor used this as an opportunity to ask the students to reflect upon the effectiveness of this approach. The students together proposed that anyone posting an authoritative source must also post a summary of the content of the source. Later they continued to improve upon this idea and soon required anyone posting an authoritative source to process it and include in their note how the authoritative source could be used to improve the ideas in the group’s discourse.

Metadiscourse

Studies have shown that when students are engaged in metacognitive activities (e.g., self-reflection, self-explanation, or monitoring), their learning is enhanced. However, metacognitive thinking is not spontaneous. Thus, it is important to incorporate metacognitive support in the design of learning environments (Lin, X. 2001). The Engineering Mechanics instructor introduced the concept of “metadiscourse” during the first KB Talk to help students reflect on their learning process and to help them make progress in their discourse. The following list includes sample questions discussed during KB Talks:

- What is your current group question?
- Are you making progress?
- What have you learned so far?
- What challenges are you facing?
- What are the knowledge gaps that you need to overcome?
- What is the next step?

The students were encouraged to extend and sustain this kind of discussion in their online discourse by opening a view called "metadiscourse" within their own group views.

Assessment

The knowledge-building component of Engineering Mechanics counted for 30% of the course grade. The assessment included three components: (1) Knowledge Forum contribution, (2) E-portfolio and (3) reflection essay. The *quantity* of each student's discourse contributions was assessed using the Knowledge Forum analytic toolkit, and the instructor judged the *quality* of each student's contributions. The E-portfolio assessment was an adaptation from the knowledge-building portfolio assessment proposed by Lee et al. (2006). In the E-portfolio students reflected on the idea improvement in the discourse, selected important notes, and discussed how those notes contributed to the understanding of the group as well as their individual understanding. Finally, in the reflection essay the students revisited a video that they found earlier in the course of a tornado impacting a structure. In their essay they wrote about how their ideas had changed during the semester with respect to what they noticed about the mechanical behavior in the video and what they needed to learn more about to understand that behavior. Referred to as a preparation for future learning (PFL) assessment by Schwartz, et al. (2005), this assessment approach is designed to measure what Broudy (1977) refers to as interpretive understanding.

Final rise above

Each knowledge-building group was required to complete a final rise above during the last month of the semester. The final rise above is an opportunity for synthesizing ideas developed throughout the semester and for creating an advanced cognitive artifact. The students had the freedom to choose the format of the final rise above. The final rise aboves included a letter to the local community, a presentation, an AutoCad drawing showing a house design and a designed experiment. It was stressed by the instructor that the product itself was not central to the assessment. The intended outcome was that the process of creating the final rise-above would lead to idea improvement.

Data Analysis

Assessing the effectiveness of knowledge-building pedagogy is a challenging task. In this paper we present the analyses of two data sets collected in 2010 and 2011. The first analysis focuses on assessing changes in how students conceptualize learning by examining student surveys about the role of the teacher in the classroom. Two classes of students were surveyed at the beginning and end of Engineering Mechanics. In the first class (2010) knowledge building was not used in the course. In the second year (2011) knowledge building was used. The same instructor taught the class in both years.

The second analysis focuses on assessing changes in the nature of knowledge-building contributions over time using a qualitative analysis. One group (Group 5) out of the six groups in the 2011 class was chosen for the initial analysis. This group was chosen because it was identified by the professor as the group that struggled the most with making knowledge-building progress at the beginning of the semester. However, Group 5 improved throughout the semester to become one of the more successful groups by the end of the semester. Studying the contribution dynamics and distributions within this group could potentially yield insights into building a more robust learning environment. In this analysis the student's knowledge-building notes posted on Knowledge Forum served as the primary source of data for the analysis.

1. Students' Conceptualization of the Instructor's Role

At the beginning and the end of the course in 2010 and 2011 students were asked to answer the question, "What is the role and responsibility of the teacher in advancing knowledge in this class?" Student response rates were 100% and 95% (pre and post, 2010) and 96% and 86% (pre and post, 2011).

After the responses were collected, each of them was coded, and the categories used for the coding were generated from the responses themselves. Since responses could include multiple roles and responsibilities, student responses were often coded into more than one category. Three independent readers coded the student responses and the calculated inter-rate reliability was 85%. As shown in Table 1, student responses were sorted into fourteen categories. The results of applying these fourteen categories to the student survey data are shown in Figure 3 (for 2010) and Figure 4 (2011).

Figure 3 shows that the largest increases in the students' conceptualization of the instructor's role during the 2010 semester are explaining clearly (+14.5%) and providing tools and resources to help students solve complex problems (+5.3%). The largest decreases are providing fundamental big ideas (-16.4%) and guide students to self-direct their own learning (-8.0%). Figure 4 shows that the largest increases during the 2010 semester are guiding students to self-direct their own learning (+10.4%) and facilitating student collaboration (+5.6%). The largest decreases are using professional skills to direct student thinking (-7.2%) and motivating students by making material interesting (-6.2%).

#	Category	Specifications	Sample Responses
1	To be Available	Responses concerning the teacher availability with regards to time and helpfulness	"They should be ... approachable for help."
2	Challenge Students and Their Ideas	Response concerning the method that the teacher uses to interact with the students ideas	"Providing new ways of thinking by challenging our ideas."
3	Create a Robust Learning Environment	Responses concerning the structure and the characteristics of the class	"…the responsibility of the teacher is to create a learning environment where students feel engaged and comfortable participating in class."

4	Demonstrate Real Life Examples	Responses concerning the teacher's use of real life examples	"The teacher leads through all the new concepts. And shows us real life problems."
5	Enable Students to Apply Concepts to Various Situations	Responses concerning the teacher enabling the student to develop a thorough understanding of the concepts in order to apply them	"The teacher not only teaches us new knowledge, but also helps us to apply the knowledge we've learned into application."
6	Encourage Creative Ideas and Innovation	Responses concerning the teacher welcoming innovative ideas from students and integrating creative ideas into teaching material	"...encouraging students to think outside the box."
7	Explain Things Clearly	Responses concerning being knowledgeable and being able to effectively present the course content	"…and taking the time to clearly articulate the material."
8	Facilitate Student Collaboration	Responses concerning interaction between students and their collaboration	"…the role and responsibility of the teacher is to facilitate discussion…"
9	Guide Students to Self-direct Their Own Learning	Responses concerning teacher's guidance in students' own learning with emphasis on students initiated exploration and reflection	"They are not just a teacher of certain materials but must be an advisor to stimulate and encourage self-exploration and growth as a student."
10	Use Professional Skills to Direct Student Thinking	Responses concerning the teacher's authority in knowledge, which is used to direct the students to specific outcomes that the teacher has determined.	"...direct people to the correct answer via various methods."
11	Motivate Students by Making Material Interesting	Responses concerning using interesting material or teaching in an engaging way to attract students' attention	"…and make the topic as interesting as possible…"
12	Pay Attention to Individual and Ensure That Every Student Understands	Responses concerning paying attention to each individual's learning styles and different levels of understanding	"The teacher must go to each student and actually tried to answer individual problems and questions he should be open to various students' backgrounds and take that into account when teaching different material in this course."
13	Provide Fundamental Big Ideas	Responses concerning basic concepts, their relations to one another, and the general overviews	"…and teach us the basics but fundamentals so we can use the basics to solve more complicated/creative problems…"
14	Provide Tools/Resources for Students to Solve Complex Problems	Responses concerning tools/resource (e.g. diagrams, models, books, links, formulas)	"…the teachers responsible for providing the tools and background to allow the students to better understand and expand on the material."

Table 1: Specifications of categories for coding categories and sample responses

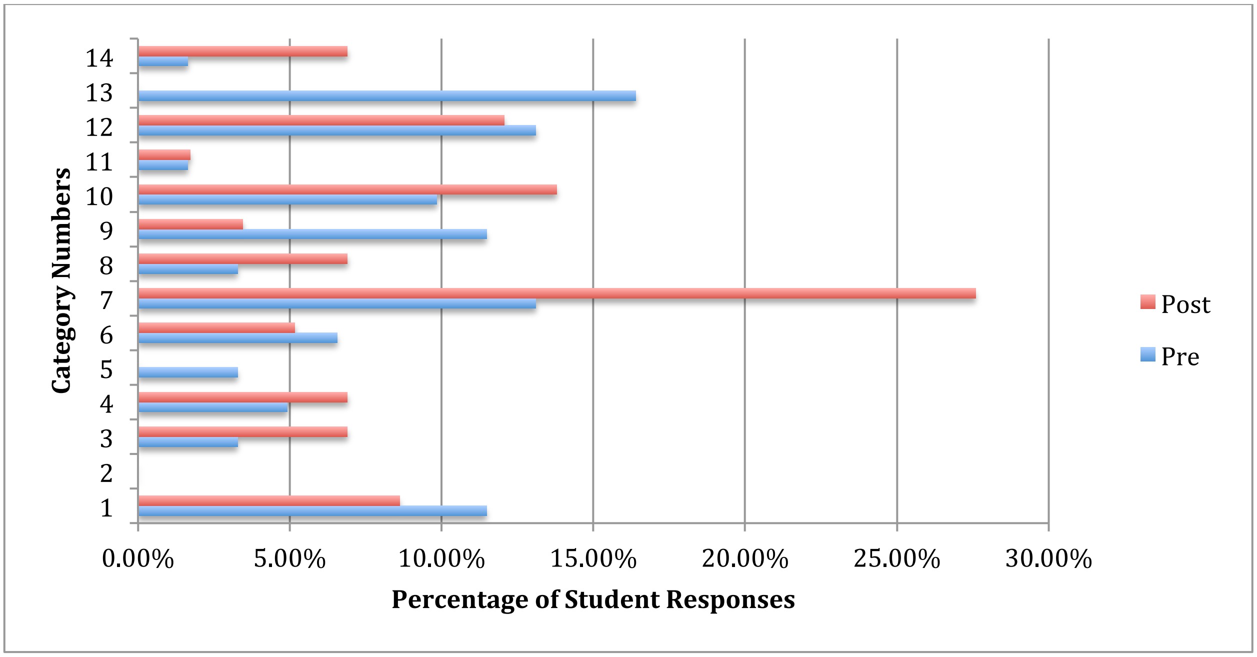

Figure 3: Results of anonymous student survey conducted on first and last day of Engineering Mechanics class in 2010 (without knowledge building).

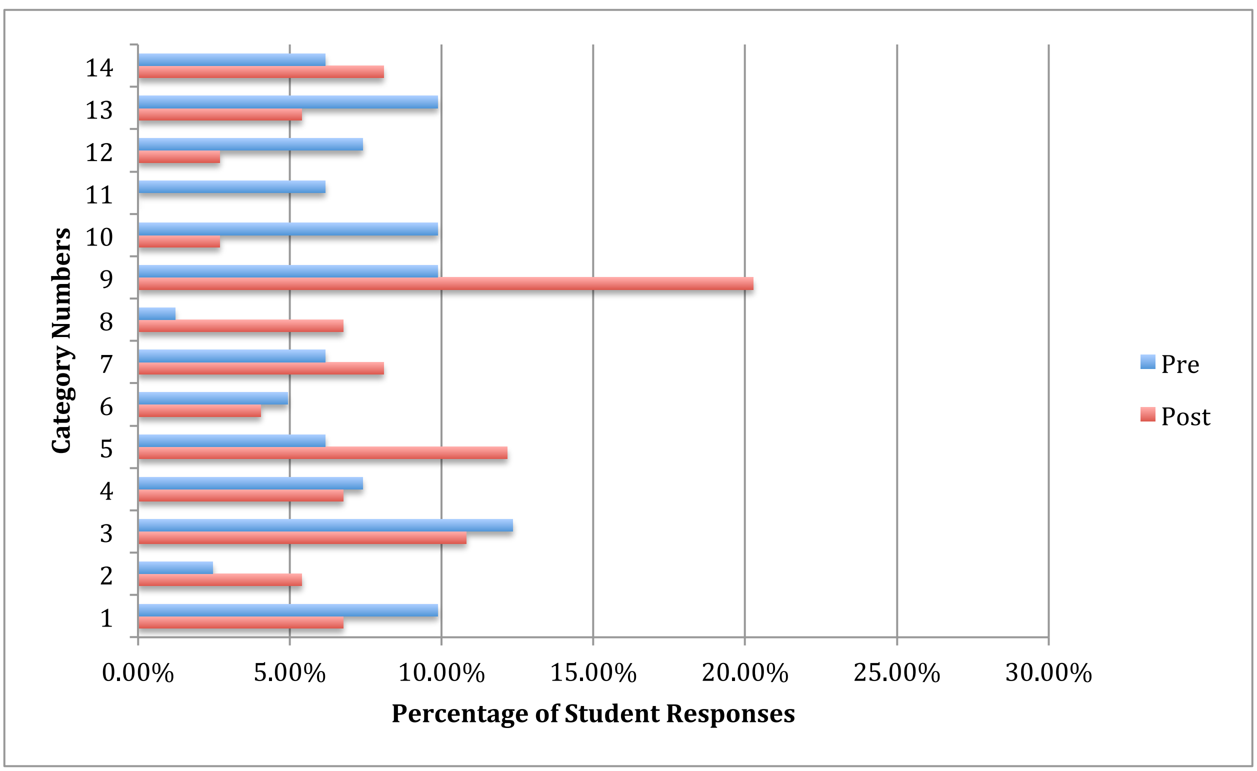

Figure 4: Results of anonymous student survey conducted on first and last day of Engineering Mechanics class in 2011 (with knowledge building).

2. Changes in Knowledge Building Contributions Over Time

Based upon the work of Chuy et al. (2011), an initial list was developed for categorizing the contribution types of student knowledge-building notes. Following a ground theory approach (Glaser & Strauss, 1967), this list was used to inform and guide the analysis of the knowledge-building discourse. Tables 2 and 3 explain the categories identified through the above process for coding questions and coding statements. In some cases notes fell into multiple categories. Forty percent of the notes were coded by all coders and used to establish an inter-rater reliability of 84%. In all, 338 notes were coded: 64 of these came from the first half of the semester while 274 came from the second half of the semester.

Figure 5 shows how the nature of the student contributions changed during the semester. It shows a change from sharing facts to theorizing, synthesizing and supporting other group members. The percentage of notes dedicated to factual questions went down dramatically, but explanatory questions continued to be asked at the same rate throughout the semester.

Main category	**Sub-Category**	**Description**	**Sample Notes**
Theory building	**Factual**	Asking for facts, information	"How do we get a hold of these building codes? Are they open to the public, and who is in charge of them?"
	Explanatory	Asking for explanations	"How are the forces applied in the compression lab causing shavings to come off? Is it a result of the forces or the factors resulting from the application of force like heat or friction?"
Non-Theory building	**Metacognitive**	Reflective questions asking "are we making progress", "what are the challenges", and questions showing progressive problem-solving or epistemic agency.	"[I need to understand]: whether we are focusing on the building codes of a specific city or state or just building codes in general."
	Task Oriented	Questions focusing on tasks, such as those asking for specific steps for completing a task, or those initiating collaboration on a task.	"Maybe we could try to find a way to contact that professor?"

Table 2: Descriptions of categories for coding questions.

Category	Sub-Category	Description	Sample notes
Theory Building	**Facts**	Adding new facts without developing or advancing a theory	"Each town or city in Massachusetts creates its own building and zoning codes."
	Theorizing	Proposing an explanation Supporting an explanation Improving an explanation Seeking an alternative explanation	"[My Theory]: is that houses are designed to rely on the roof as loading force that holds the walls together."
	Working with evidence	Providing evidence or a reference to support or challenge an idea	"I've been looking into their FORTIFIED housing design and I noticed they prescribe metal straps to hold the roof to the top floor. This intrigued me because, based on the information collected from their interview, the roof blowing off is a strategic failure ... Tying the roof down seems contrary to this notion."
	Synthesizing	Synthesizing available ideas Creating analogies Initiating a rise-above	"I think we all agreed that having no response is not a solution. Although it is true that many people in Springfield may never again experience a tornado in their lifetimes, to use that as a reason NOT to prepare is plain careless and (I think) unethical."
Non-Theory building	**Supporting discussions**	Giving an opinion Expressing an agreement (without furthering the idea)	"That is a fantastic idea!" "I agree that its important to look into how a tornado acts and that we need to take thorough notes to come up with ideas about how a tornado causes damage."
	Epistemic Agency	Reflecting on the discourse, offering suggestions for moving forward. Notes demonstrating progressive problem solving and metacognitive thinking.	"I think that narrowing our research will help give us direction. I think in order to help us do that, we must collectively decide on a distinct location of this house, and a certain set or range of conditions we expect for the tornado."
	Strategic Talk	Announcing and updating strategic plans. Or initiatives, such as distributing labor, or getting the group to focus on one task	"We need to figure out a system for appointing people to write up week summaries and make sure that we are moving along."

Table 3: Descriptions of categories for coding statements.

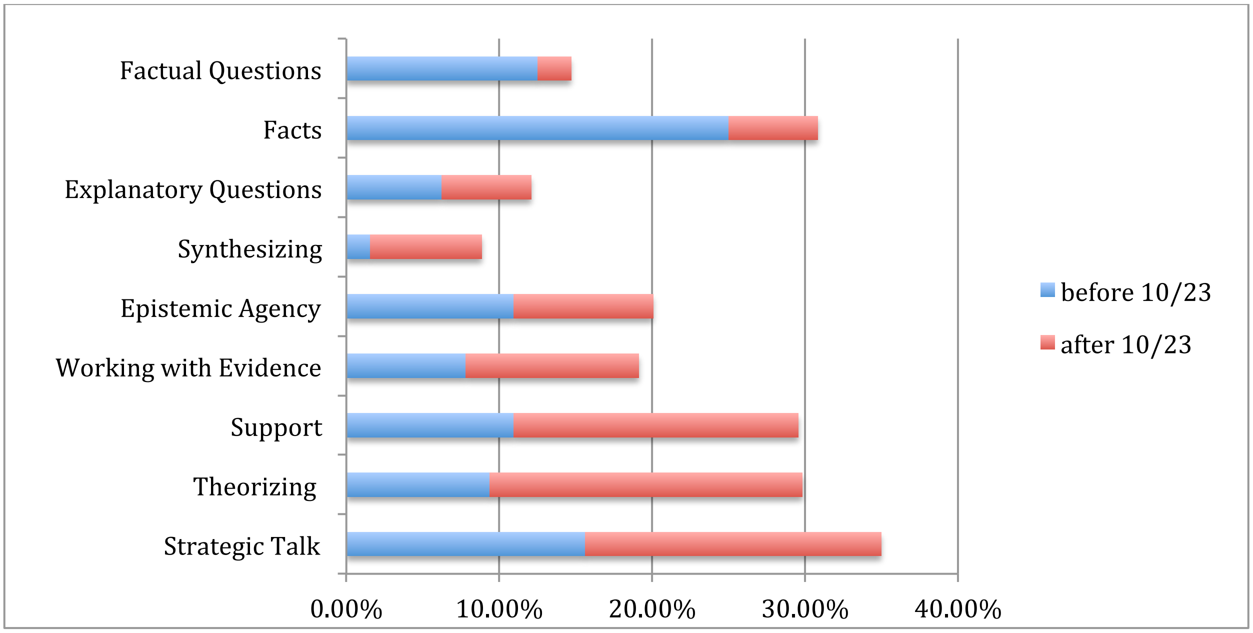

Figure 5: Coded Knowledge Forum student notes comparing contributions from the first and second half of the semester. 10/23 signifies the middle date between the first day of Knowledge Forum use, 9/14, and the final date to post on Knowledge Forum, 11/16.

Discussion

Knowledge-building pedagogy redirects responsibility for advancing knowledge and learning from the teacher to the learner, so it is particularly interesting to see if students view the role of the teacher differently after taking a course that includes knowledge building (and recognizing that a single course may have limited impact on student thinking). In particular, categories 6, 8, 9 from Table 1 (encouraging creative ideas and innovation, facilitating collaboration, and guiding students to self-direct their own learning) are consistent with a learner-centered classroom and may change after experiencing knowledge building. Figures 3 and 4 show student responses that are consistent with developing a more learner-centered approach to learning due to knowledge building. In 2010—before knowledge building was integrated into the course—category 9 (self-directed learning) showed a large drop after students completed the course. By contrast, in 2011 the largest *increases* were in category 9 and category 8 (facilitating collaboration). In 2011 the largest decreases after taking the course were in categories that are teacher-centered.

Although the development of knowledge building is based upon the research on how people learn, assessing the learning that takes place remains a challenge for expanding the application of this pedagogy. This is due in part to the greater focus of knowledge-building pedagogy on helping students develop interpretive understanding. Although developing interpretive understanding is at the heart of deep learning and supports further learning and transferring knowledge into new situations, it is challenging to assess with traditional assessment instruments (Schwartz, et al., 2005). In this paper we have presented a first attempt at analyzing knowledge-building discourse in order to assess changes in the way students participate in discourse over time. In particular, do students advance from just sharing facts to actually working collaboratively on idea improvement?

First of all, as students became more engaged and comfortable with knowledge building, their overall contributions increased dramatically from 64 in the first half of the semester to 274 in the second half of the semester. In addition to a large increase in all contributions, the nature of the contributions changed over time. Throughout the semester students continued to post explanatory questions at about the same rate, but dramatically decreased the rate at which they asked factual questions. Asking explanatory questions, collectively building theories to answer them and then creating improved explanatory questions is fundamental to effective knowledge building. Although sometimes important in theory improvement, factual questions do not seed or drive knowledge-building discourse.

In terms of theory-building statements, three of the four categories increased during the semester with only facts decreasing. This showed that students progressed to theorizing, working with evidence and synthesizing—all more advanced forms of contributing to knowledge building. In particular, the notes categorized as synthesizing increased greatly (both in terms of percentages and particularly in terms of absolute numbers). This increased use of theory-building statements places the student's ideas, and thus the students, at the center of the learning environment. This finding is consistent with the survey results showing the knowledge-building class gravitating toward a more student-centered conceptualization of the learning environment. Such an occurrence would not be expected in a traditional classroom model where the teacher's authoritative knowledge— rather than the student's inquiry—provides the structure for the learning environment.

Percentage contributions of non-theory building statements remained fairly constant throughout the semester, and thus increased about four-fold in absolute numbers. Students were clearly providing supporting statements for their team members' ideas. They were also engaging in the strategic talk and in talk showing epistemic agency (both elements of metadiscourse) that is necessary for effective teamwork and knowledge building.

Conclusion

We have presented the application of knowledge building into an introductory engineering mechanics class. Based upon survey results of student opinions on the role of the instructor in the classroom, there is evidence consistent with knowledge-building pedagogy changing students' conceptualization of learning from being more teacher-centered to being more learner-centered. An analysis of one knowledge-building group's discourse shows changes in student contributions to the discourse consistent with more effective knowledge building. This included student questions becoming more explanatory and student statements being more focused on theory building.

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