



The Design of Language for Engineering Education: Recycling IM and Text Messaging to Capture Engineering Processes

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**(A Foreign Language not so Foreign)
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Abstract

In an ideal world, teachers would be able to track the rationale of individual students or student groups and communicate with students continuously rather than at the end of a project or at milestones. Current design rationale tools tested in industry show that engineers (and students) have to break their momentum to stop and record ideas or document, so those tools are not as effective as they could be. A previous research project comparing different types of media used for documentation in a high school engineering project course showed that in situ video offered instructors deeper insight into the thought processes of students and their learning than design journals, storyboards, or digital photographs (author ASEE 2012 paper). A natural continuation of that project was to use the video to observe natural communication patterns, themes connected to engineering design, and engagement between students within groups and between teachers. Those observations, combined with the recognition that digital technology and social media have permeated our culture and classrooms, give us an opportunity to use digital technology and social media to our advantage as researchers and educators.

A tool that allows seamless communication and documentation would be ideal for both students who want to communicate conversationally and teachers who need to assess learning and want to see process thinking. This project looks to fill that gap by designing a language currently popular with students (and some adults) to be the foundation framework for a future design rationale tool. Using live video from student groups and classroom sessions and based on research in computer-mediated communication and literacy, we generate a classroom text and IM language that can be used to facilitate communication between students and improve engagement between students and instructors during the engineering design process. The language includes abbreviations and icons specific to engineering and design processes, and reflects interaction behaviors in the relationships between students, groups, and teachers. This language can then be taught to students and teachers to test its efficacy in supporting documentation, reflection, and assessment.

Introduction

Engineering standards are being adopted in public education to expose K-12 students to engineering thinking and concepts at earlier ages^{1,2}, hoping to impact STEM interest and long-term career decisions. Design is an integral theme and skill in engineering³, thus making design thinking important in engineering education and K-12 STEM courses. “Design thinking is an approach toward learning that encompasses active problem solving by engaging with (Dewey, 1916), and changing the world. Language is a central to this view, as we communicate and engage in dialogue with others (Bakhtin 1981)” as cited in⁴. With appropriate language, teachers in engineering and design classrooms would be able to trace thinking through the design rationale as the design proceeds and communicate efficiently with students with quicker

turnaround, not just retrospectively or from static project artifacts. They could also use technology to supplement teaching documentation and communication.

Because of its permeation into culture, the ways that teenagers and kids use technology, and the commercial development of tools such as iPads, tablets, kid digital cameras that support kids using technology, education would be irresponsible to ignore the opportunity to use cultural technology methods of communication to impact pedagogy and assessment in K-12 engineering education. Approximately three-fourths of teens have cell phones^{5, 6} and over 50% of teenagers 17 and younger have access to the Internet outside of school and send email or text messages at least once a week. The median number of text messages sent a day by teenagers is 60 a day, although the numbers range from zero to greater than two hundred⁶. Sixty-three percent of teens use text messaging daily more than any other form of communication (phone, instant messaging, emailing, and face-to-face socializing)⁶. In order to use technology and its language effectively, it should be used in a manner that is comfortable and convenient for students.

In *Visual Thinking for Design*, Ware defines language as “a socially developed system of shared symbols, together with a grammar”⁷. Since 80 percent of adults 18 and older also send text messages⁸, there are shared symbols and grammar used in that medium upon which educator can capitalize for the classroom. Finally, “Gee’s (1996) now-familiar distinction between “little-d” *discourse* as language- in-use and “big-D” *Discourse* among participants in a community of practice” as cited in⁹ is helpful in setting the stage for a classroom-based language where we assess thinking through discourse. This study is phase two of an assessment design project for K-12 engineering classrooms. Previously collected data of classroom brainstorm sessions and group interactions were used to create a language that can be piloted in classrooms and used as a framework for supporting interaction and communication between students and teachers and potentially assessing change in student thinking.

Theoretical Frameworks

Design

Design education classrooms use the studio critique and design notebook to facilitate recording of student thoughts and verbal expression of ideas¹⁰. The dialogue between student and design notebook, and students with each other and teachers create a rich medium for evaluating student understanding¹¹. Often design rationale tools are used to capture thinking as projects progress toward completion. Some advantages that design rationale tools offer include support for redesign, reuse, maintenance, learning, documentation, collaboration, and management of projects and dependencies¹². While these tools have many advantages, design rationale capture tools share a challenge with science notebooks or journals when used as assessment tools and teaching tools in the classroom for a variety of reasons. Students often bring diverse ways of knowing, talking, and interacting that are different, and often in conflict, with mainstream classroom practices. Research in science education has shown that school science could be a point of identity conflict and cultural language challenge¹³⁻¹⁷ for minority students and assessment methods could value a particular way of articulating one’s understanding phenomena¹⁴. This puts students that cannot master or demonstrate mainstream expressions of understanding at a disadvantage. Though text messaging and IM are informal languages, they both are mainstream languages in the lives of youth.

Language as Learning and Assessment

Integrating engineering and design into K-12 engineering education has obstacles which include, but are not limited to, curriculum placement, class time, content expertise of teachers, and assessment¹⁸. Attempting to use language in and as assessment requires us to look at how conversations have been viewed in learning and assessment. Research shows many perspectives on learning and assessment conversations, including but not limited to, conceptual learning conversations, feedback conversations, assessment conversations, and instructional dialogues. We used these conversations to guide our observations of interactions in the classroom, and we offer a brief survey of their summaries.

Pea describes conceptual learning conversations as conversations where students in small groups use symbols and terms in authentic activities, where conceptual change occurs via conversational repair and appropriation of learner activities^{19,20}. Feedback conversations “convey the point that domain-specific conversation is itself feedback that helps communities of learners participate in those very conversations”⁹. Assessment conversations are conversations where assessment can occur because teachers have sufficient content and pedagogical content knowledge to respond spontaneously and interpret student understanding from student comments and guide without delay²¹. Instructional dialogues are verbal encounters between either the teacher and the student or among students²¹. Most instructional dialogues are analyzed based on the work of Bellack et. Al.^{21,22}, where four types of moves occur: structuring, soliciting, responding, and reacting. *Structuring* moves set context for subsequent moves. *Soliciting* moves elicit verbal or physical responses. *Responding* moves are reciprocal to soliciting. *Reacting* moves serve to modify or evaluate a previous move.

Mercer describes exploratory talk as classroom talk where reasoning is explicit through questioning assumptions, presenting rationale for claims, persuading, and stating evaluation and critique²³⁻²⁵. The other categories of classroom talk from Mercer’s research are cumulative and disputational talk, but they are less likely to support co-construction of knowledge in a design or engineering setting.

Assessment practices should maximize opportunities to demonstrate diverse students’ knowledge and abilities in ways compatible with their backgrounds²⁶ and can reflect current social phenomena. There is great potential for using cultural behaviors of social media, IM, and text-messaging to increase achievement for all students and equalize assessment for disadvantaged students if research can offer insight into efficient use in classrooms.

Research Questions

The research questions were:

1. In what ways do rising high school seniors interact with each other and their design problem?
2. What symbols could be applied to themes or communication behaviors?

Methods

Context and course

The course where the video was captured is one course in a four-week college preparation summer program. Twenty-two high school students (14 girls, 8 boys) of various immigrant and minority backgrounds applied as eighth graders and were accepted into a four-year college preparation program for disadvantaged students. These students are first or second generation immigrants from Africa, South America, and the Caribbean, and most of them speak English, a native language, and a cultural dialect. They were rising high school seniors with intentions of attending college and were expected to be the first generation within their family to attend a four-year university.

As seniors, the course was the culminating summer of the four year academic and residential summer program, and students have been exposed to a variety of science coursework through the college preparation program and their respective high schools over four years. Students worked in teams of 2 to 4 on weeklong projects with themes of design, civil, and electrical engineering. Because students have indoctrinated to a program mission and served in cohorts over the course of their tenure in the program and had the same instructor the entire time, this context is considered in a community of practice²⁷.

The class was constructed to mimic a reality television show where the class was a design firm and students were designers on teams. Though the lab classroom was not set up with overhead cameras or film crews capturing continuous surveillance, students were given digital cameras and access to video cameras to record work sessions, and the instructor recorded sessions as well. This resulted in a dataset of 27 in situ video clips.

Since the goal of this phase of the project is to develop a language from in situ video reflecting authentic student-student and student-teacher interactions, in situ video data have been transcribed with HyperTRANSCRIBE and analyzed using grounded theory^{28, 29} with DeDoose software. DeDoose software allows coding of transcripts, audio, and video clips. Verbal transcripts of teams were used to generate the first round of interaction behavior categories. The first round of categories is then used to apply to multiple video clips and verify categories. The stage of the design process spotlighted in the paper is the brainstorm phase, so only clips of brainstorming phase were used to generate categories.

Results

Results from the first round of grounded theory coding^{28, 29} reveals interaction behavior categories. These twelve major interaction behavior categories are *question*, *mind change*, *reasoning*, *identify problem*, *decision*, *choice*, *action plan*, *fix*, *checklist*, *reflection*, *uncertainty*, and *cancel*, and we share our definitions. There were multiple types of *questions*, from both teacher (usually redirecting) and students, so there are subcategories. *Question* subcategories include: *interrogatives* of why, what, how, when, or where; *redirecting* back to task or a topic, *clarifying* for understanding meaning, and *reconsidering* alternatives or missing pieces. A *mind change* occurs when a student is going in one direction with a thought but switches for a stated reason. *Reasoning* happens when an idea is evolving, through *expanding* to make it larger, *deepening* a specific aspect, responding to a *constraint*, or *consideration* of a factor. Students *identify problems* in the process of thinking through both the initial task and any solutions they might put forth. *Decisions* can be made together *confirming* mutual agreement, after options

have been given and a *selection* is made, or just executively. *Choices* are made from *binary* options or a *range*. An *action plan* describes a series of tasks or intentions where something tangible will result. A *fix* is a solution to a situation in the brainstorm process, and sometimes it is the *response* of a student-identified problem. *Reflections* are admissions that show a critique or evaluation of something they have or have not done. *Uncertainty* is demonstrated mainly in two ways, by *not remembering* or *not knowing* something. Students often *cancelled* an idea because of something they felt was wrong with it or because they did not want to figure out how to explain it verbally.

Table 1 shows a frequency chart of the interaction behaviors from a sixteen-minute video clip of one design team. The clip and transcript capture a brainstorming session between two students and a teacher as students narrow down their idea and work through the obstacles. The most prevalent behavior in this excerpt is *clarifying questions* with 6 codes, followed by *identify problem*, *interrogative questions*, *mind change*, and *deepening the idea* with 4 instances.

Interaction Behavior	Type (Subcategories in <i>Italics</i>)	Code Frequency
Question	Interrogative (Why, How, When, Where, What)	4
	Redirect question	1
	Clarifying question	6
	Reconsider question	
Mind change		4
Reasoning	Layering idea (expanding idea)	2
	Deepening idea (digs into one specific part of idea)	4
	Constraint	1
	Consideration	1
Identify problem		4
Decision	Decision	1
	Confirmation	1
	Selection	1
Choice	Binary selection	0
	Range	

Action plan		1
Fix	Response	2
Checklist		0
Reflection	Remembering and discussing what was done or not done	2
Uncertainty	I don't know	2
	I don't remember	
Cancel	Never mind	2

Table 1. HF Transcript Interaction Category Frequency Chart

Figure 1 shows an excerpt from the corresponding verbal transcript from the same group HF. This excerpt should provide examples of the difference between interrogative and clarifying questions, and deepening and broadening ideas. Codes are underlined and in superscript.

I mean what else?

You want to try an incorporate two designs in one. ^(Broadening idea)

H: Yeah. Because like you said, there's a transmitter here. So not only sound so they can hear it. But also like, let's say if the blind if the street is too noisy, ^(Identify problem) and he can't hear it there should be something specifically designed for him to hold so like I know I'm saying ^{(Broadening idea)(Response)}

F: To hold? What do you mean? ^(Clarifying question)

H: Yes to hold. So like if it goes by instead of hearing it only you so they feel it.

F: What if its three blind people at the bus stop? ^(Identify problem) ^(Interrogative question)

H: What about that? ^(Clarifying question)

F: I think we should make a distinct sound? ^(Response) ^(Deepening idea)

H: A distinct sound? ^(Clarifying question)

F: Yeah, I think sound it makes will have impact. And then even put like the instruction of it in braille or something. I dunno. ^(Uncertainty-I don't know) Uhm, I think we only got the receivers

Figure 1. Coding example of Group HF, Lines 82-94

Symbol Development

Next, we identified symbols which could be the foundational elements for an K-12 electronic design journal and IM or text messaging symbols. The graphical symbolic language will be modeled after the rationale elements set described in DRed (Design Rationale editor) ¹² that was foundation for the design rationale software tested in industry. DRed had multiple icons that were used to code documents, and this seemed to be more helpful in getting engineers to document as they went rather than reflecting at the end of a project.

The base element we suggest is the lightbulb, representing an idea, and various actions upon an idea. This helps to track *iterations* (author, 2012), measures of evolution in projects and student

thinking. The idea behind the icons are to find icons that students already see and have meaning to them that would be easy for teacher or student to draw, if necessary. Then additions to the base symbol offer extra meaning. Figure 2 shows a teacher drawn collection of the images.

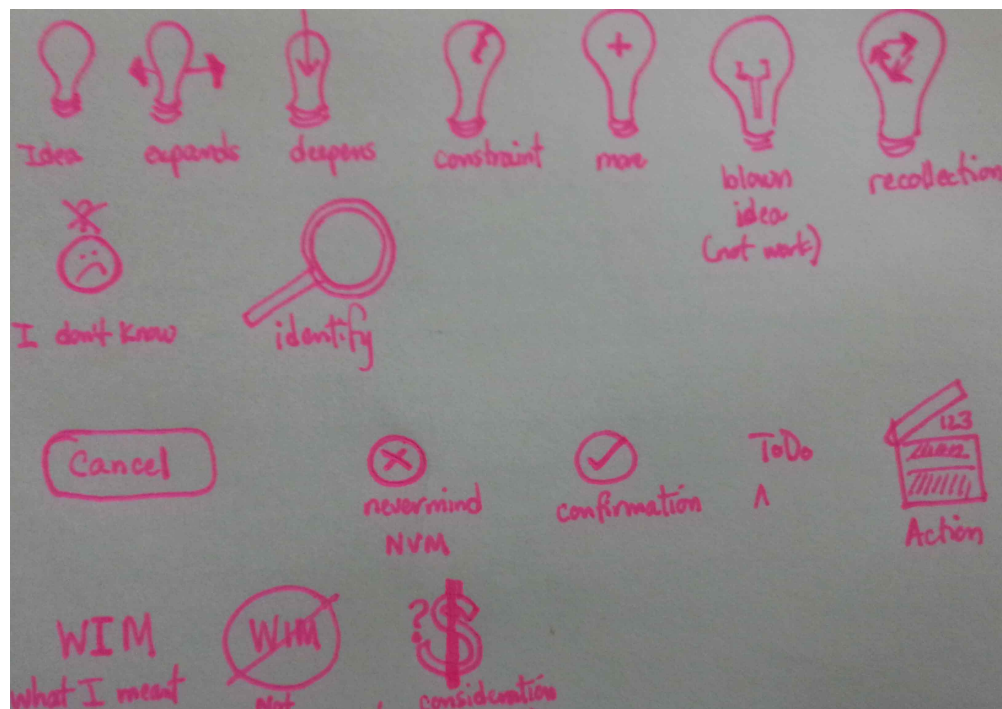


Figure 2 Symbols that might represent interaction behaviors used in an electronic design rationale tool.

Figure 3 shows the first attempt at implementing the symbolic language to analyze a design team interaction. It shows the same transcript excerpt of group HF and also corresponds to the frequency chart and coded interaction behaviors in Figure 2.

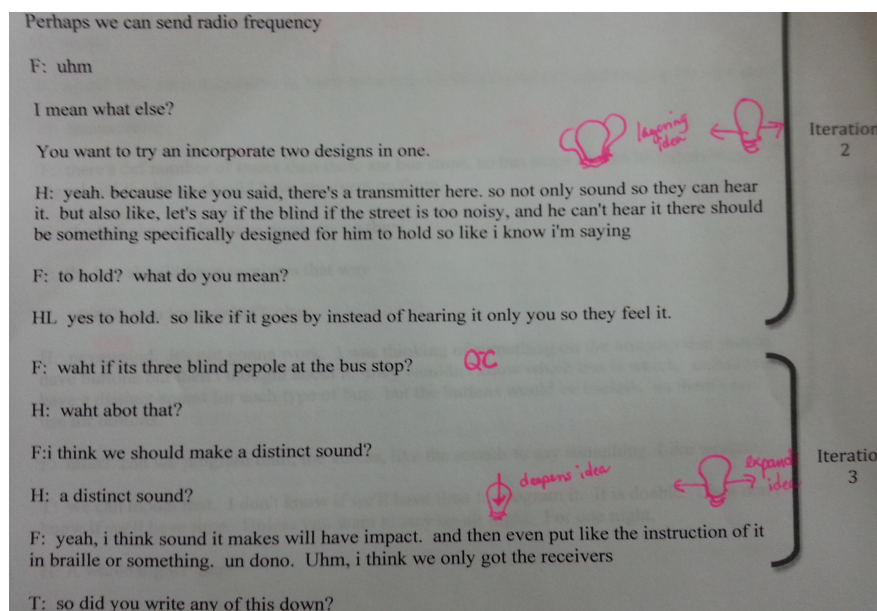


Figure 3 Image from Round One of Coding a Design Team HF Interaction Using Icons.

In an electronic design journal interface, each idea path would be tagged with a light bulb, and then light bulb icons would change to reflect expanding, deepening, blown, and constraints. If multiple idea pathways are generated, light bulbs will have colors to reflect “active”, “held”, and “discontinued” stages.

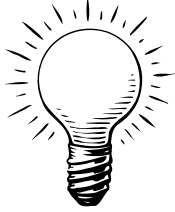



			
Idea/Undecided	Discontinued/Stopped	Active/Go	Held/slow

Table 2. Interface Icons Reflecting the Status of Ideas

Even if the light bulb is a color, icons could change to reflect deepening of an active idea, for example. Instructors and students can archive ideas so if a pathway is not fruitful, teachers can remind or redirect students to other light bulbs, or students trace their thinking. Since students are used to the coloring of the stoplight, green would be “active,” yellow would represent “held,” and red indicate “stopped or discontinued.” With this schema, even younger students could use the interface.

If these symbols are then given abbreviations or icons for the sake of text messages or coding design journals, they would look like the symbols in Table 3.

Element	Abbreviation
Idea	LB
Expanding idea	$\Leftarrow LB \Rightarrow$
Deepens idea	$L \downarrow B$
Idea Constraint	\cap LB
Broken idea	L/B
More Ideas	$\oplus LB$
Nevermind	\otimes
Confirmation	\checkmark
Action	$123<$
What I Meant	WIM
That's Not What I Meant	$\emptyset WIM$

Table 3. Interaction Elements and Abbreviations

Finally, we have attempted to superimpose the symbolic codes in icons and abbreviations on the transcript excerpt from group HF in Figure 4. Only *identify problem*, *deepening* and *expanding idea*, and *cancel* behaviors are highlighted in this excerpt as it is a partial demonstration.

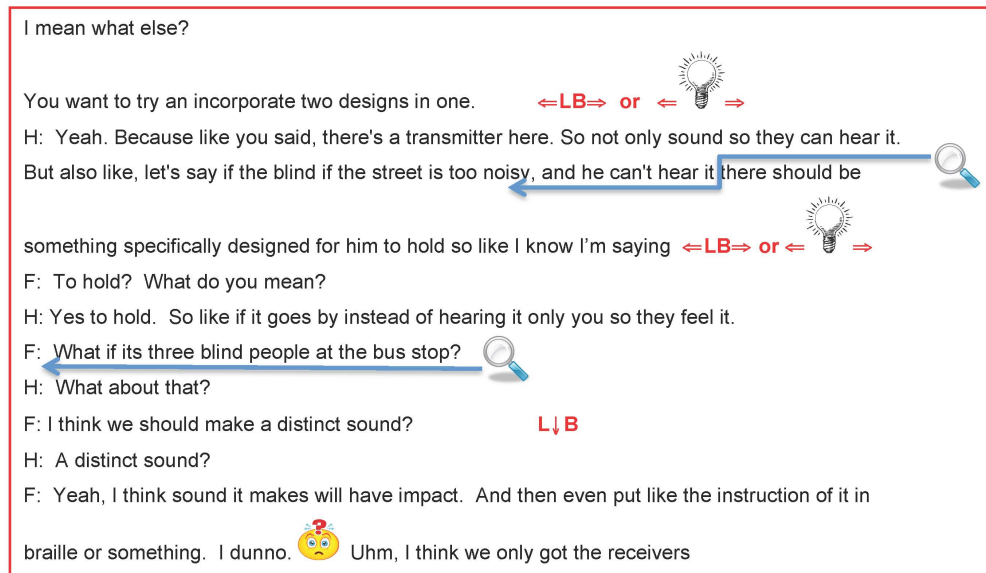


Figure 4. Analysis of group HF transcript with selected codes and icons (Expanding and Deepening idea, I don't Know, and Identify Problem) applied.

Conclusion

The purpose of this paper was to use *in situ* video data from student design classrooms to identify authentic interaction and communication behaviors and guide the development of a symbolic language that will make student-teacher communication and teacher assessment easier. We wanted to take advantage of the popularity of text messaging and icons used in social media and efficiently use it in K-12 engineering and design spaces to support improved communication. As the second phase of a research experiment, we used previously collected data to generate a coding framework based on the interaction behaviors within design teams and between teachers and students. We researched interaction and learning conversations to guide us in the types of categories we should be observing in our video clips. We found that this group of students had high instances of mind change, and were quite consistent about asking clarifying questions and identifying problems as they moved through brainstorming.

This paper focused on the brainstorming stage of the design process, and we fully expect the behavior categories *mind change*, *reasoning*, *decision*, *choice*, and *fix* to evolve further as we analyze the prototyping and testing phases of the teams. As we continue to develop this interaction and symbolic language, we will continue to make comparisons to existing learning conversation models.

The interaction behaviors discovered from this experiment were collected from high school students, and there is a possibility that those interactions will apply to elementary and middle school students, but that must be validated. Understanding that language is emergent and that language has subtle differences across cultures and within communities of practice, the framework for the language is based on these interaction behaviors and offer these symbols as a foundation. The informality and freedom in social media allows people to add to the language, and it is hoped that teachers and students would take the foundational elements and expand upon them for their context. As each teacher and classroom maintains its own community of practice,

we encourage ownership so that the communication is authentic. As we continue to develop the language, we understand that we must teach the language to both teachers and students and pilot it in middle and high school classrooms to get feedback. There is much potential for positively impacting use of design journals in assessment, improving teacher feedback, and documenting design rationale of students in an innovative manner that has a smaller learning curve because students already use the language of social media in their nonacademic lives.

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