AC 2012-4535: THE REALITY SHOW OF A HIGH SCHOOL SCIENCE, ENGINEERING, AND DESIGN COURSE: OBSERVING DOCUMENTATION AND COMMUNICATION PATTERNS TO INFORM PEDAGOGY AND ASSESSMENT

Tamecia R. Jones, Purdue University, West Lafayette

Tamecia R. Jones is a doctoral student studying assessment in K-12 formal and informal spaces at the Purdue University School of Engineering Education. She has a B.S. in biomedical engineering from the Johns Hopkins University and a M.A. in learning, design, and technology from Stanford University. She is a certified middle school math and science teacher and has created STEM outreach programs for a variety of K-12 populations.

Dr. Monica E. Cardella, Purdue University, West Lafayette
Dr. Senay Purzer, Purdue University, West Lafayette

Senay Purzer is an Assistant Professor in the School of Engineering Education and is the Director of Assessment Research for the Institute for P-12 Engineering Research and Learning (INSPIRE) at Purdue University. Purzer has journal publications on instrument development, teacher professional development, and K-12 engineering education. Her research focuses on assessing constructs such as innovation, information literacy, and collaborative learning.

The Reality Show of a High School Science, Engineering, and Design Course: Observing Documentation and Communication Patterns to Inform Pedagogy and Assessment

Introduction

There are multiple challenges to introducing engineering into high school classrooms. These include, but are not limited to, curriculum placement, class time, content expertise of teachers, and assessment[1]. Often time limitations force simultaneous teaching or integration of design, engineering, and technology in science courses. When this happens measurement of learning and conceptual development has to be navigated in lessons that have layers of content or skills, and assessment of working knowledge and conceptual knowledge can be challenging. Ideally, teachers would be able to trace thinking through the design rationale as the design proceeds, not just retrospectively or from static project artifacts. They would also be able to use technology to supplement teaching documentation and communication. The use of technology and cultural technology methods of communication has potential to impact assessment in K-12 engineering education. Seventy-five percent of teens have cell phones[2] 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. Twitter and other text-messaging tools help to motivate and encourage students to do more writing and encourage interactions between students[3]. Instant messaging (IM) is real-time "interactive written discourse" and teens multitask while using IM[4]. Some teachers are using IM to help students spark ideas and creativity[3], but IM could potentially be used as an assessment tool. In order to use it effectively, it should be used in a manner that is comfortable and convenient for students. This study is phase one of an assessment design project for K-12 engineering classrooms.

Theoretical Frameworks

Science Journals

Often science journals and rubrics are used as assessment tools. Science journals or reflective logs help teachers to document what students have learned and how student understanding has changed [5-7]. They also create useful references for class projects and future investigations [8] and since students can use science journals that hold notes from all previous courses instructors can spend more time on other important aspects of the lesson because students can quickly find past notes and return to prior knowledge [9].

Design

Designers spread their work over both physical and digital artifacts, and project-based design courses feature interplay between individual ideation and reflection and group brainstorming, discussion, and presentation. Two important components of design education are the design notebook and the studio critique. In the design notebook, students take class notes, sketch, and write down design ideas, observations, inspiration and reflections. The studio critique is a form of peer learning and forum for students to comment, brainstorm, critique, and solve problems after groups have presented their work to classmates[10]. This public presentation of ideas inspires

ownership of thought and responsibility as well as practice of metacognitive habits and cognitive reflection[11]. It also requires students to have documentation of their thinking when defending ideas or engaging in dialogue with classmates. The dialogue between student and design notebook, and students with each other and teachers create a rich medium for evaluating student understanding [12]. Communication is the linchpin of both of these components.

The advantages that design rationale tools offer include support for redesign, reuse, maintenance, learning, documentation, collaboration, and management of projects and dependencies [13]. This challenge of design rationale capture tools is similar to the challenge of science notebooks or journals being used as assessment tools and teaching tools in the science classroom. Students often bring diverse ways of knowing, talking, and interacting that are different, and often in conflict, with mainstream classroom practices. How do we really know what students are learning based on documentation and communication? Research in science education has shown that school science could be a point of identity conflict and cultural language challenge[14-18] for minority students and assessment methods could value a particular way of articulating one's understanding phenomena[15]. This puts students that cannot master or demonstrate mainstream expressions of understanding at a disadvantage. Since many engineering concepts are introduced or integrated in science classroom contexts, we wish to avoid the inequities these experiences create as assessment techniques evolve by investigating different assessment techniques. Assessment practices should maximize opportunities to demonstrate diverse students' knowledge and abilities in ways compatible with their backgrounds[19]. 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. A comparison of traditional tools of documentation and communication should be compared to digital forms of documentation and communication as the foundation for this work.

Research Questions

The research questions were:

1. What practices (design notebooks, photographs, storyboards, or video) help student reflection in the design process?
2. What does comparison of design notebooks, photographs, storyboards, and video provide for teachers when evaluating student learning?

Methods

In order to compare natural tendencies or previously learned behaviors in science journaling that would transfer to design notebooks, students took notes in daily lectures and completed homework in journals without a formal structure given in how to do so for this program setting. Students were also allowed and encouraged to take digital photographs of their iterations of projects. Students were required to create design storyboards at the beginning and conclusion of each project. Video recordings of final presentations were captured on testing day as well as some ongoing recordings of classroom activities and brainstorm sessions. Some video clips were shown in the classroom to provide data for updating journals or ideas. Video clips were used as pedagogical tools and later served as a data source. All of these sources of student work or

reflection have been collected to complete a portfolio. Five student portfolios were selected as cases to sample the class and gather observations[20]. These student cases were chosen based on the clarity of their drawings in journals and on storyboards. The design journals, design storyboards, and video will be used in content analysis. Systematic coding of these data sources will be used to analyze text and verbal discourse and make comparisons of the type of observations that come from the various media[21].

Video scenes have been transcribed and coded for iterations of project evolution. An *iteration* is defined as a change, addition, or reduction of a project idea. The transcripts are compared to design storyboards and design journals to see if iterations appear in either storyboards or design journals. Photographs are matched with iterations and design journal entries.

Data Sources

The data is intended to identify techniques for improving teaching so that design journals are more thorough and reflect more of the critical thinking, reflective practices, and decision-making processes of students. The observations from the data will help to develop a coding language that can be piloted in classrooms and used as a framework for assessing interaction between students and teachers. The framework is the foundation for development of symbolic graphical language similar to texting language that uses abbreviations and icons. This symbolic graphical language can then be taught by teachers and serve the purpose of a cognitive apprenticeship [5] so that students might more effectively use design journals as they are moving through the design process rather than as final products in the project package. The graphical symbolic language will be modeled after the rationale elements set described in DRed (Design Rationale editor) [13] that was foundation for the design rationale software tested in industry, but will be designed for use in K-12 classrooms. The final outcome of the project is the foundation for a pedagogical method and seamless tool that lends structure to student thinking and is beneficial in the recording process rather than a hindrance.

Context

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 are rising high school seniors with intentions of attending college and are expected to be the first generation within their family to attend a four-year university. It is a national federal program that has sites on college campuses across the country, but this particular site is located in a northeastern urban center. These students hail from multiple public high schools, parochial schools, charter and pilot schools within this city.

Course

This course is one course in a college preparation summer program. As the culminating summer of a four year academic and residential summer program, students have been exposed to a variety of science coursework through the college preparation program and their respective high schools over four years. The course is entitled "Applied Science" for two reasons. The first reason is that students have taken intensive introductions to earth science, biology, chemistry, or physics over the past three years, but this particular course has no specific content focus in any

traditional discipline. Secondly, directors and instructors wanted to introduce engineering via the design process, and cover the state engineering and science frameworks.

The course consisted of four weeks of instruction and design process practice and included weekly quizzes and projects and a final exam. There were four eighty-minute blocks each week. There were weekly projects, but students were rarely able to complete projects in the time allocated so extra time was allowed during evening study halls. The problem of the first week was the redesign of the umbrella. The second week theme was civil engineering with a special focus on bridge design. The tangible project was a bridge made of spaghetti, epoxy, and hot glue able to withstand 1kg of weight. The third week theme was electrical engineering and had an open-ended project where the intent was to improve the quality of life for an individual with an illness or disability. Students were to prototype a product that included an actual circuit if possible. The final week involved prototyping and construction of any projects and final testing day.

Theme	**Project**
Design Process	Umbrella Redesign
Civil Engineering	Spaghetti Bridge
Electrical Engineering	Disability product

Table 1 Course Schedule

Each section of the course contained eleven students. Students were allowed to choose their own partners or group members for projects, and were not required to stay in the same groups for every project. Groups could not be more than three members, and usually students worked in trios or pairs. One project involved an individual student. There were usually three to four teams per class per project. For purposes of identification, student and group samples provided in this paper are referred to with initials of the student or members, also indicating group size.

Results

Design notebooks, photographs, storyboards, and video helped students reflect on the design process at varying levels. Among all artifacts, video was the best medium for reinforcing reflection and validating student observations when comparing to design notebooks, storyboards, and photographs. Using video helped trigger student memory of events and improve reflection (later in this section we provide evidence of this from the storyboards). This reflection happened through verbal conversation more than documentation, but there were occurrences of increased detail in documentation in student journals.

Students did not take *photographs* during brainstorming or construction of projects. The instructor took photographs of final products and compared them to post-construction storyboards. This might be due to the fact that there was not time to generate multiple prototypes, so students could not compare prototypes over time.

Design storyboards are useful in helping students generate context for the problem, describe the user, and how the product will be used. They offered beginning and end snapshots of the product, but did not help the students to trace design rationale. The original expectation that

documented versions of the iterations and reflective decisions made will be lower in number than what the photographs and video show are evidenced in transcripts from the in situ video.

Transcripts from the *video* scenes show that generation of the storyboards caused additional brainstorming and decision-making, but without in situ video most of the artifacts would show little evidence of all of the decisions and iterations. Most project groups submitted pre-construction storyboards and post-construction storyboards, but none of the groups submitted multiple storyboards as their projects evolved. Figures 1-5 show transcripts of group FH generating a storyboard where in a ten-minute period there were five iterations.

F: oh so like put receivers in teh bus that so like that send signals to each other so when its close enough they can like i don't konw what it is but its just like there's certain things that respond to ohter things when they're in a certain range from each other

T: right

F: so if we put that on the bus and make it a certain range so that as soon as it hits reaches that range it starts beeping and making the noise so the blind person know the bus is relatively close and it can start signalling for the bus to stop.

Iteration 1

Figure 2. Excerpt from video of group FH brainstorming session showing excerpt of iteration 1.

wouldn't be useless for the blind. nevermind, that's for the deaf. ahhh, that's pretty much it.

Perhaps we can send radio frequency

F: uhm

I mean what else?

You want to try an incorporate two designs in one.

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, and he can't hear it there should be something specifically designed for him to hold so like i know i'm saying

F: to hold? what do you mean?

HL yes to hold. so like if it goes by instead of hearing it only you so they feel it.

Iteration 2

Figure 1 Excerpt of group FH transcript showing iteration 2.

F: waht if its three blind pepole at the bus stop?

H: waht abot that?

F:i think we should make a distinct sound?

H: a distinct sound?

F: yeah, i think sound it makes will have impact. and then even put like the instruction of it in braille or something. un dono. Uhm, i think we only got the receivers

Iteration 3

Figure 3 Excerpt of group FH video transcript showing iteration 3.

F: i think.

H; what?

F: would it be more expensive to have some transmitting signal or something receiving signal?

H: transmitting

F: there's def number of buses than there are bus stops, so bus stops should be transmitting signal and the buses should have receivers on them.

H: the bus should also have receivers on them

F: the bus should have receivers that way

H; o0000h you know what? okay.

H: nevermind. it's not gonna work. I was thinking of something on the bus stop that should have buttons but then i thought about it. they wouldn't know which bus is which. unless you have a distinct sound for each type of bus. but the buttons would be useless. so there's no use for buttons.

Iteratio: 4

Figure 4 Excerpt showing iteration 4

[00:55:23.315]

H: oh how about this? yo. so you said transmitter receiver right? so the bus is coming by it transmits a sound to the sign because they bothe have radio frequencies whatever on it circuitboard and then it makes a distinct sound. that's how you know which bus is withc uh, bus is which and you know you put braille on somehting. you can put braille on buttons so they feel which one which and they they click it and they indicate to the other bus so it can goes both ways and tells the bus driver in there that they want to stop.

F: what? say that again?

H. you feel me? ok. so the bus is coming by right? and then its transmitting to the bus stop. its waiting for a reply from the blind dude to see which bus he wants. the blind dude touches a button and he figures out which one because (its written in braille.)? which one it is because he hears it. and he touches which one it is. one sound would be 47, another sound would be 55, another sign would 10. whatever nubmer it is.

Iteratio
5

Figure 5 Excerpt showing iteration 5, the final iteration that matches the pre-construction storyboard.

These iterations do not appear in any of the group member design journals. However, iteration 5 appears in the pre-construction storyboard (Figure 6a). The only journal entry from group FH after the pre-construction storyboard is the circuit schematic used in the design (Figure 6b).

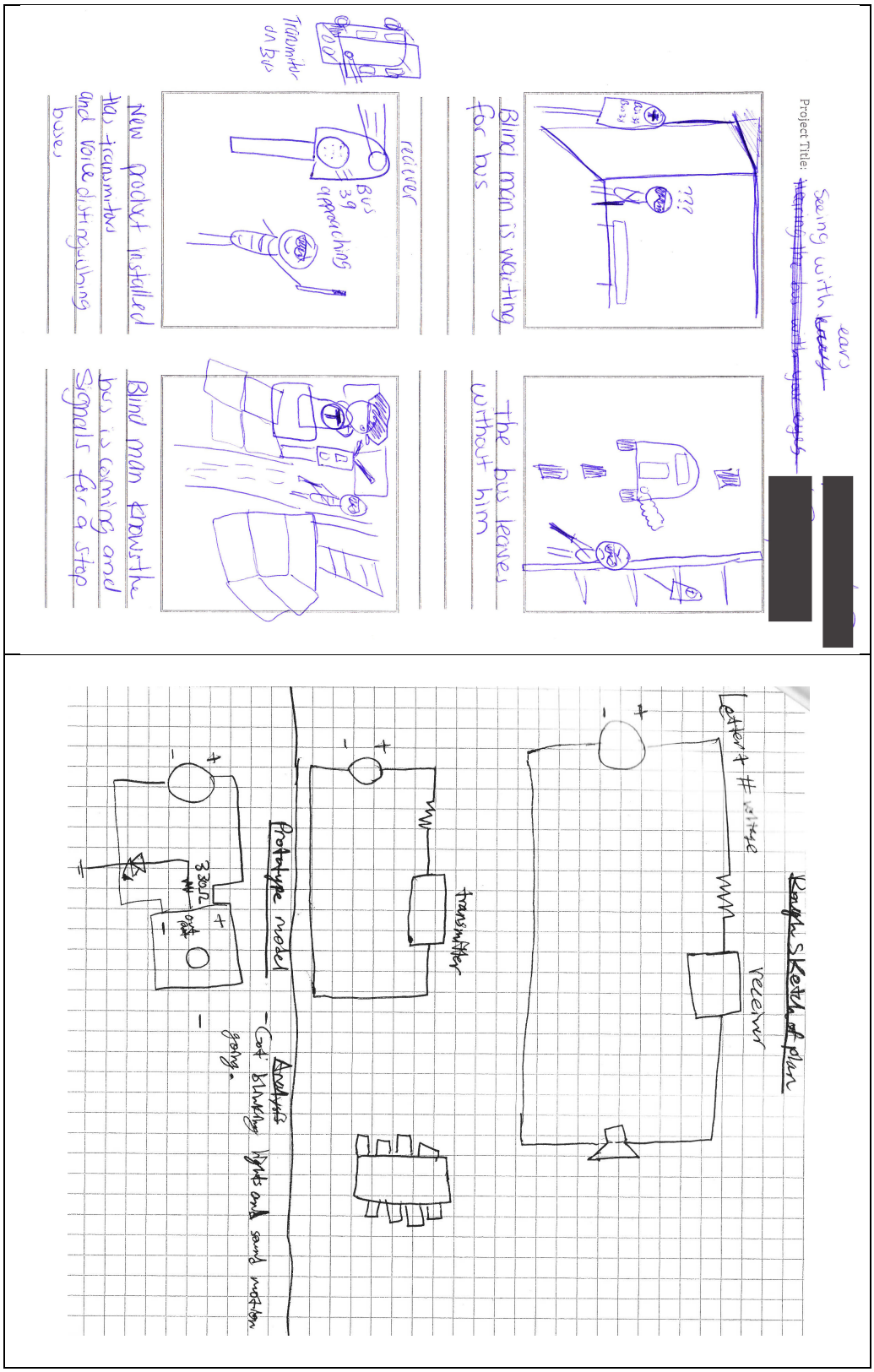

Figure 6 Pre-construction storyboard (a) and product journal entry (b) of Group FH

Video transcripts also show that students switched project goals and ideas without submitting storyboards for all of the projects they considered. They submitted storyboards for projects they decided to build. Finally, video provides instructors with documents and artifacts that students did not submit for review or assessment. An example of this is from Student J's journal entry (Figure 7) and storyboard (Figure 8) that differ dramatically from the photograph of a scrap drawing (Figure 9) and the final product (Figure 10.) Figure 9 is an image captured from the video that has not been found anywhere in student J's portfolio.

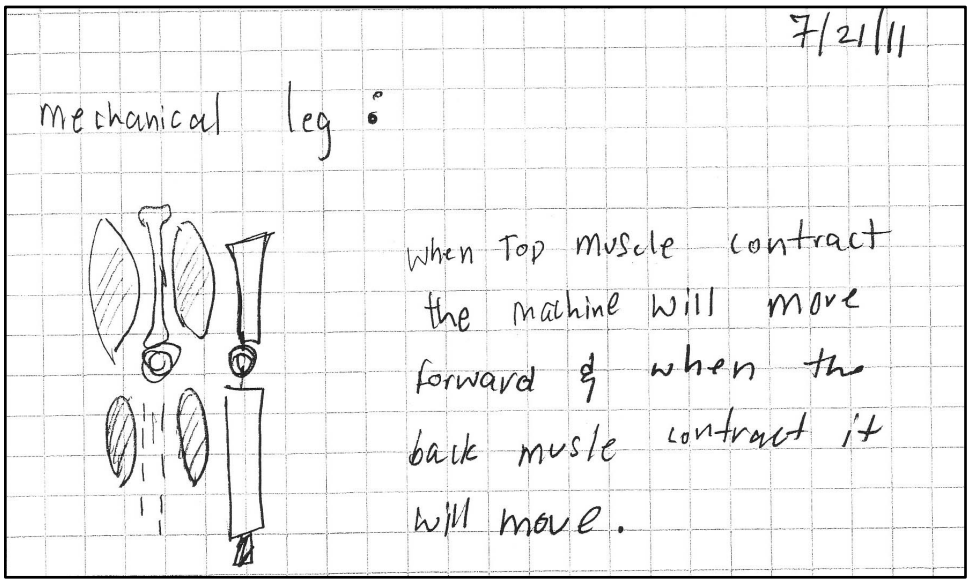

Figure 7 Journal entry of student J

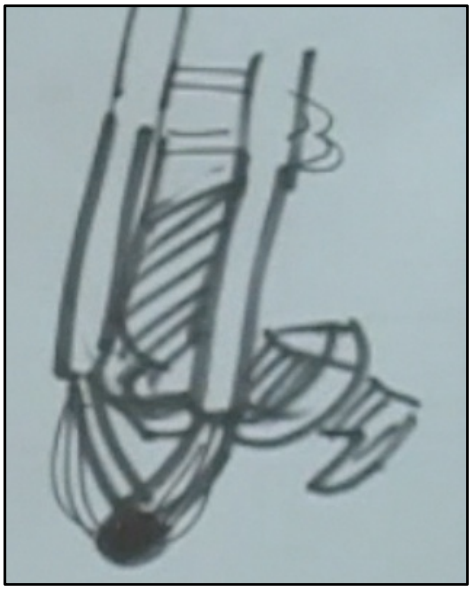

Figure 9. Scrap Diagram of Crutch

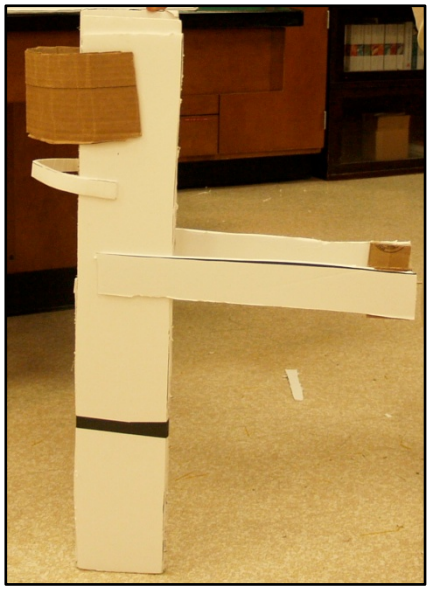

Figure 10 Final prototype of crutch

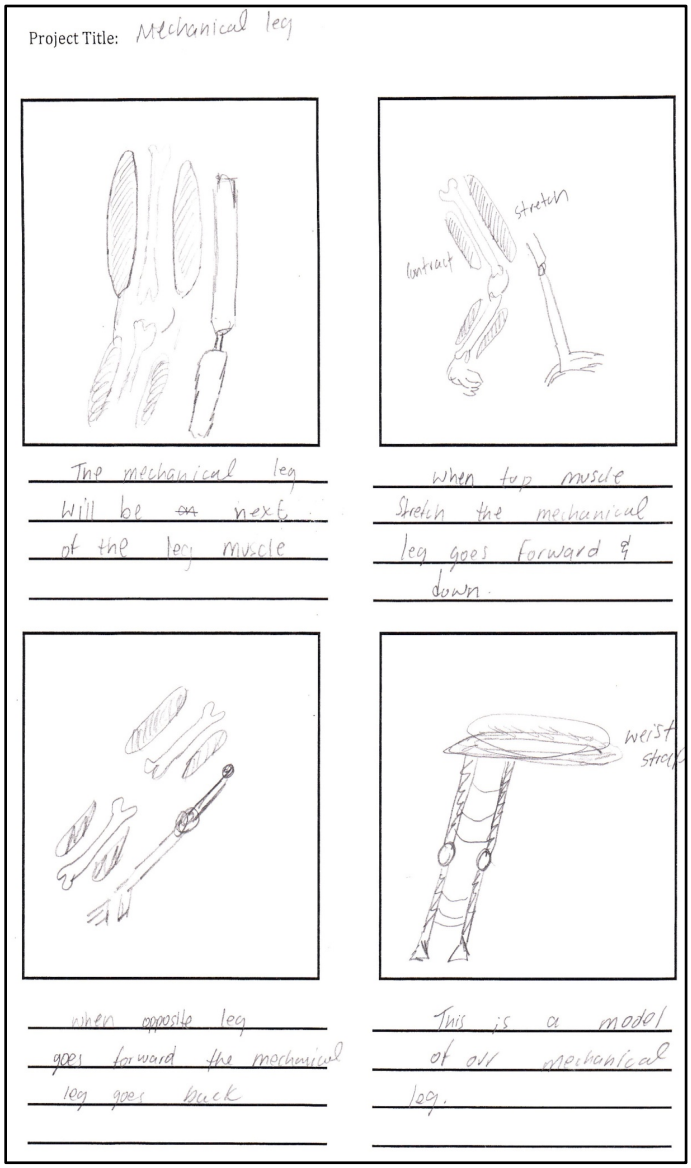

Figure 8 Student Pre-construction storyboard

Instructors can use media and the collection of artifacts to measure different forms of student learning. *Design journals* provide content data that students are using to inform decisions. *Design storyboards* help instructors to understand the context for which the student is applying their knowledge and offer markers for comparison in assessment of learning. *Photographs* offer details that are not written or drawn clearly. *Videos* offer rich data from in situ recordings. In addition to the comparison of transcripts to submitted documents, another example of assessment potential is comparing vocabulary quiz grades with vocabulary appropriately used in demonstrations and experiments. *Videos* also serve as pedagogical tools for anchored instruction[22]. In the umbrella testing and scenario recreation, students tested three umbrellas by pouring a bucket of water from the top of a parking garage onto a student an umbrella at the garage entrance. Video footage was taken, volunteer students drew diagrams, and the rest of the class conducted visual observations. After the class finished the experiment, students wrote

observations, interviewed the umbrella holders, and watched videos to see if their observations were comprehensive and note differences from their real-time observations.

Before the reviewing of the video:

- Four of the five journals students describe and draw three different shapes of umbrellas.
- Diagrams are unspecific about hand placement of holders or the way the water hit the umbrella and how the umbrella responded to the force of the water.

After the viewing of the video:

- Two of the five cases included images that were more specific about bending of the umbrella and hand placement.

These images were summarized on the whiteboard after the video clips were viewed a class discussion led to consensus about the details of the scenario. The images are shown in table 2.

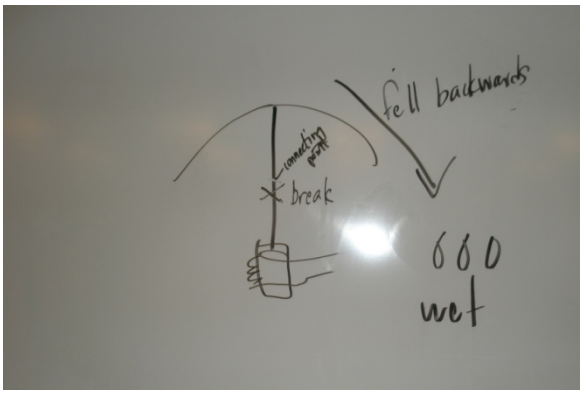

Figure 11 Holder A reflection of experience

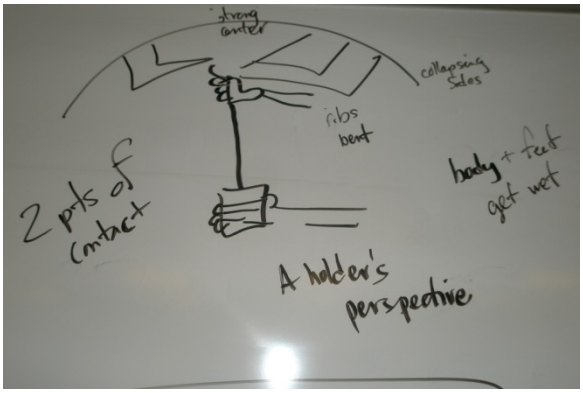

Figure 12 Holder B reflection of experience

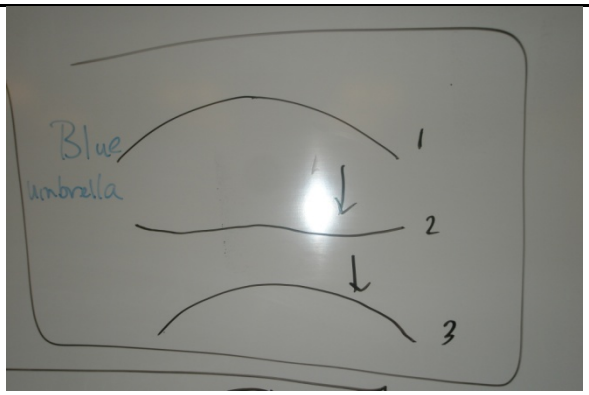

Figure 13 Shape changes of blue umbrella

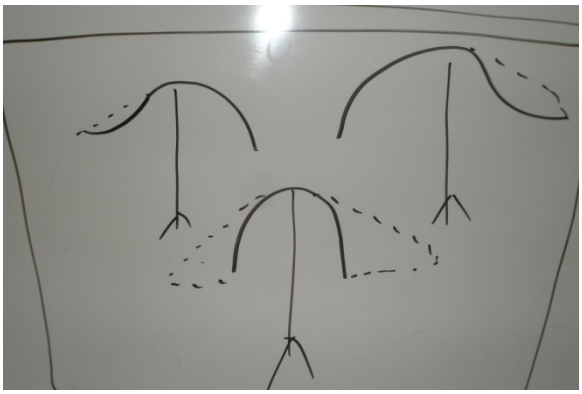

Figure 14 Diagrams of force of water pressure on various umbrellas

Table 2 Summary of video observations translated to graphics

The journal entry in Figure 15 shows an evolution of detail and information as the student documents in real-time, reflects, and watches a video. Researcher annotations highlight the transitions and differences in details.

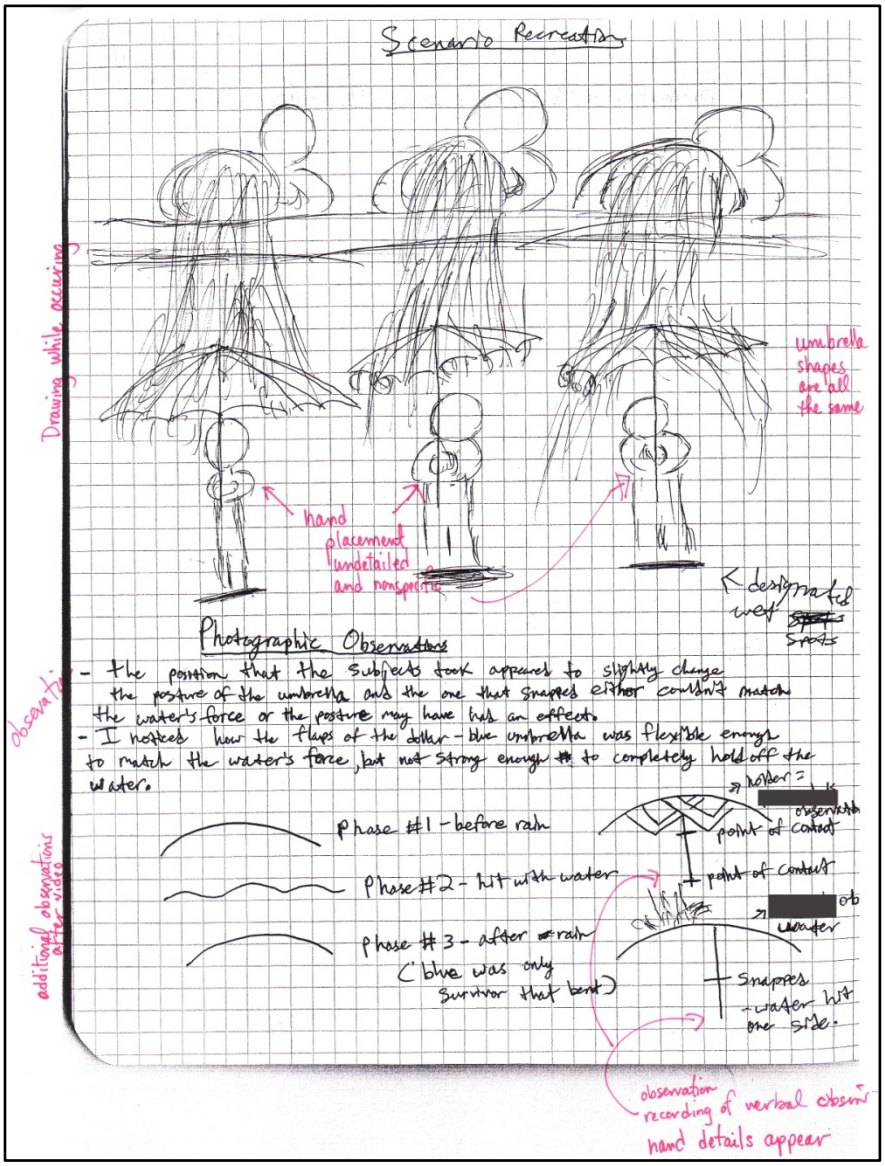

Figure 15 Annotated journal entry showing three stages of reflection

Conclusion

Data show that in situ recordings offer data that standardized testing, tests, quizzes, project rubrics, photographs, and science and design journals do not provide. True process and evolution of ideas has to be done with a tool that is continuous and more seamless, and this is where research can advance assessment. Computer-mediated communication reproduces the discursive style of face-to-face spoken language and IM allows participants to be present at the same time "electronically"[4] while using a language that is familiar and comfortable to them. It is indeed a form of interactivity that can be recorded and analyzed[23] and a source of data for assessment. The next step in this research is to use the transcripts from the video recordings from the student cases to generate a primitive IM or symbolic graphical language. The symbolic graphical language is a language that would be taught and incorporated into the pedagogical methodology and used as a tool for both communication and assessment. It will be composed of

codes and icons similar to that of text messaging. The framework of the language can then be validated by comparison to transcripts, journals, and storyboards from the rest of the class. If we are able to model communication behaviors, we will be able to effectively design assessment tools that can trace design rationale and offer real-time continuous data.

Though cell phones and or SMS have been used in education to increase interactivity[24-27], there are debates about whether or not texting affects literacy[28, 29]. It is being considered an alternative literacy that is changing the way young people communicate[30-32] and researchers are looking to design for use in the classroom[33]. Instruction should enable students to connect their cultural norms with mainstream expectations[19]. If instructors view IM, SMS, and CMC as a tool for teaching, engaging, and assessing students, instructors could capitalize on the current cultural behaviors of students and interact with them at higher levels. Allowing for nuances of individual student communication style, identity, and recording behavior, tools that support individuality reduce tension between classroom expectations and external expressions of knowing. Simulating natural behaviors of students will improve the educational experience for students and increasing efficiency in assessment for teachers. Future goals of the research include identifying the best mechanisms for improving teaching, engagement, and assessment in engineering education contexts.

Though the focus was not on team choice and experience, research suggests that patterns might be visible in the migration across and between teams or lack of team change. Students might be making decisions about team or partner choice for reasons that they do not communicate explicitly. Video recordings have the potential to show interpersonal dynamics experience and self-efficacy and participation of individuals on teams. Such information could be useful for educators when creating teams or pairs or in assessment of individuals in project-based classes. This research also suggests that students might benefit from increased opportunities to reflect on their design practices. Without aids such as video recordings, students may forget some of the key design activities they engaged in, and therefore may miss the value in the opportunity to reflect on those design activities. Educators could encourage their students to create a video-based design journal (similar to the video reflection activity described by McDonnell et al. [34]), or they might capture video of class sessions which the instructors could include in future class sessions. While there are logistical considerations (e.g. an instructor would need to obtain students' permission before creating the video recordings), the use of videos to prompt reflection is a promising educational practice. Additionally, the findings in this paper support the notion that design thinking and learning are not always captured in design artifacts, so video recording group design sessions is important for collecting a more comprehensive account of the design thinking and learning that takes place.

References

1. Rushton E, Cyr M, Gravel B, Prouty L. Infusing Engineering into Public Schools. Paper presented at: American Society for Engineering Education, 2002; Montreal, Quebec, Canada.

2. Lenhart A, Purcell K, Smith A, Zickuhr K. *Social Media & Mobile Internet Use Among Teens and Young Adults*. Washington, DC: Pew Internet & American Life Project; 2010.
3. Tomita D. Text Messaging and Implications for Its Use in Education. Paper presented at: Technology, Colleges, and Community Conference, 2009; Honolulu, HI.
4. Tagliamonte SA, Denis D. Linguistic ruin? LOL! Instant messaging and teen language. *American Speech.* 2008;83(1):3.
5. Klentschy M. Making Meaning With Notebooks. *Science and Children.* 2010;48(3):8-9.
6. Deaton CM, Deaton BE, Leland K. Interactive Reflective Logs. *Science and Children.* 2010;48(3):44-47.
7. Waldman C, Crippen K. Integrating Interactive Notebooks. *The Science Teacher.* 2009;76(1):51-55.
8. Mintz E, Calhoun J. Project Notebook. *Science and Children.* 2004;42(3):5.
9. Lener E. Reuse That Notebook! *Science and Children.* 2010;48(3):56-59.
10. Lee B, Maldonado H, Klemmer SR. *Evaluating Augmented Idea Logs for Design Education.* Palo Alto: Stanford University; 2006.
11. Audet R, Hickman P, Dobrynina G. Learning logs: A classroom practice for enhancing scientific sense making. *Journal of Research in Science Teaching.* 1996;33(2):205-222.
12. Svarovsky GN, Shaffer DW. Design Meetings and Design Notebooks as Tools for Reflection in the Engineering Design Course. Paper presented at: 36th Annual Frontiers in Education Conference, 2006; San Diego, CA.
13. Bracewell RH, Ahmed S, Wallace KM. DRed and design folders: a way of capturing, storing and passing on-knowledge generated during design projects. Paper presented at: ASME International Design Engineering Technical Conference (IDETC' 04), 2004; Salt Lake City, UT.
14. Brown BA. Discursive identity: Assimilation into the culture of science and its implications for minority students. *Journal of Research in Science Teaching.* 2004;41(8):810-834.
15. Brown BA. "It isn't no slang that can be said about this stuff": Language, identity, and appropriating science discourse. *Journal of Research in Science Teaching.* 2006;43(1):96-126.
16. Brown BA. The Politics of Public Discourse: Discourse, Identity and African-Americans in Science Education. *Negro Educational Review.* Jul 01 2005;56(2/3).
17. Brown BA, Reveles JM, Kelly GJ. Scientific literacy and discursive identity: A theoretical framework for understanding science learning. *Science Education.* 2005;89(5):779-802.
18. Brown BA, Spang E. Double talk: Synthesizing everyday and science language in the classroom. *Science Education.* 2008;92(4):708-732.
19. Lee O. Culture and language in science education: What do we know and what do we need to know? *Journal of Research in Science Teaching.* 2001;38(5):499-501.
20. Yin RK. *Case Study Research: Design and Methods* Vol 5. 4th ed. Thousand Oaks, CA: Sage Publications, Inc.; 2009.
21. Strauss A, Corbin J. *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. Newbury Park, CA: Sage; 1998.
22. Bonk CJ. YouTube anchors and Enders: The Use of Shared Online Video Content as a Macrocontext for Learning. Paper presented at: American Educational Research Association, 2008; New York, NY.

23. Choudhury M, Saraf R, Jain V, Mukherjee A, Sarkar S, Basu A. Investigation and modeling of the structure of texting language. *International Journal on Document Analysis and Recognition.* 2007;10(3):157-174.

24. Markett C, Sanchez IA, Weber S, Tangney B. Pls turn ur mobile on: Short message service (SMS) supporting interactivity in the classroom. Paper presented at: IADIS International Conference Cognition and Exploratory Learning in Digital Age (CELDA), 2004.

25. Markett C, Sanchez IA, Weber S, Tangney B. Using short message service to encourage interactivity in the classroom. *Computers & Education.* 2006;46(3):280-293.

26. Scornavacca E, Marshall S. TXT-2-LRN: improving students? learning experience in the classroom through interactive SMS. Paper presented at: 40th Annual Hawaii International Conference on Sistem Sciences (HICSS '07), 2007.

27. Stone A, Briggs J, Smith C. SMS and interactivity-some results from the field, and its implications on effective uses of mobile technologies in education, 2002.

28. Plester B, Wood C, Bell V. Txt msg n school literacy: does texting and knowledge of text abbreviations adversely affect children's literacy attainment? *Literacy.* 2008;42(3):137-144.

29. Plester B, Wood C, Joshi P. Exploring the relationship between children's knowledge of text message abbreviations and school literacy outcomes. *British Journal of Developmental Psychology.* 2009;27(1):145-161.

30. Craig D. Instant messaging: the language of youth literacy. The Booth Prize Essays. *Stanford University Program in Writing and Rhetoric. Retrieved Nov.* 2003;3:2007.

31. Thurlow C, Poff M. Text-messaging. In: Herring SC, Stein D, Virtanen T, eds. *Handbook of the pragmatics of CMC*. Berlin & New York: Mouton de Gruyter; 2011.

32. Thurlow C, Brown A. Generation txt? The sociolinguistics of young people's text-messaging. *Discourse Analysis Online.* 2003;1(1):30.

33. So WWS. The development of a SMS-based teaching and learning system. *Journal of Educational Technology Development and Exchange.* 2009;2(1):113-124.

34. McDonnell J, Lloyd P, Valkenburg RC. Developing design expertise through the construction of video stories. *Design Studies.* September 2004;25(5):509-525.