121st ASEE Annual Conference & Exposition
Indianapolis, IN
June 15-18, 2014
Paper ID #9421

Shifts in the Cultural Production of "Smartness" Through Engineering in Elementary Classrooms

Tess Anne Hegedus, The University of North Carolina at Greensboro

Tess Hegedus and Aundrea Carter are doctoral candidates working with Dr. Heidi Carlone, Associate Professor at The University of North Carolina at Greensboro. Our research team is focused on examining the potential of engineering to level the playing field for diverse elementary students, to disrupt historically narrow definitions of "smartness", and provide opportunities for elementary school students to develop their creative potential.

Heidi B. Carlone, The University of North Carolina at Greensboro

Heidi Carlone is an associate professor of science education at The University of North Carolina at Greensboro. Carlone's research uses theoretical lenses from anthropology of education, sociocultural theories, and cultural studies to understand the local/global productions of science/engineering and scientists/engineers in K-8 in-school and out-of-school settings and implications of those meanings for those historically shut out of science and engineering. Her current work examines the potential of engineering curricula in elementary schools to disrupt classroom power hierarchies and broaden definitions of "smart" students.

Aundrea D Carter, University of North Carolina at Greensboro

Shifts in the cultural production of "smartness" through engineering in elementary classrooms (works in progress)

Background/Framework

Cultural meanings of "smartness" in schools are often narrowly and problematically constructed and are consequential in sorting students and keeping them out of science and engineering. For instance, those who are deemed "smart" (by measures of grades and test scores) get afforded certain educational opportunities and pathways not afforded to those deemed "struggling" (by the same measures). Cultural meanings of smartness are problematic for other reasons. "Doing school" (compliance) is often conflated with "being smart"[1]. Narrow performances of getting the right answer or displaying knowledge are often privileged over critical thinking, creativity, and problem solving[2]. In a longitudinal study[3] of scientifically talented boys, research indicated scientific interest and abilities were helpful, but not a necessary component of getting recognized as someone with scientific promise. Likability and institutional markers of academic ability (like Academically Gifted status) were much more influential in others recognizing the boys as scientific. Students' perceptions of how they are positioned in relation to school's definitions of smartness impact their longer-term interest and affiliation.

Problematic perceptions of smartness have critical consequences for K-12 engineering. Many students and teachers have limited understanding of engineers' work. For instance, some think of engineering as more of a vocational career (e.g., people who train to be mechanics to work on cars or machinery)[4]. Others consider engineers as those with unusual skill and talent in mathematics and science versus those who have considerable creativity, ability to work well with others, and communication skills[5]. Other literature points to "nerd" and "academic-achiever" identities as gatekeepers among student engineers at the university level[6].

Focus of Research

This study examines the potential of the implementation of an engineering unit to disrupt historically narrow definitions of "smartness". We ask: what is the cultural production of "smartness" during an engineering unit (15-25 hours of instruction) in four elementary classrooms? We define cultural production as meanings produced by groups in everyday practice that reproduces and/or counters historically enduring cultural narratives[7].

We use cultural production[8] as our approach as we believe that the introduction of engineering in elementary school has the potential to open up possibilities for more equitable engineering education. By examining individual and group-level social practices with this focus, we are able to examine "new patterns of behavior and thinking" that might emerge in this context (p. 659). We argue that these "new patterns" of performance have the potential to transform the status quo for what counts as "smart" in students' positioning of themselves in relation to others and their view of themselves as people who can do and be successful in the domains of science and engineering.

Another manner in which early exposure to the principles of engineering has the potential to disrupt power differentials and conceptions of what counts as smart is in the open-ended nature of design challenges. Science classrooms have been traditionally centered on revealing one right answer. Engineering education, on the other hand, offers less narrowly defined tasks and questions enabling students the opportunity for discovering multiple solutions to a problem[9]. Environments such as these support creativity, innovation and problem solving strategies encouraging more than one right answer. As opposed to traditional, rigid science classroom practices, engineering environments can provide more equitable contexts for students to share authority, participate competently, and take ownership of their learning[10]. This claim needs further investigation; hence this study.

Methods

Four teachers (2 fourth-grade; 2 fifth-grade) engaged in a week-long professional development about the Engineering is Elementary (EiE) curriculum (Museum of Science, Boston). The focus of the professional development (led by the researchers) was to orient teachers to engineering and technology, uncover misconceptions, and provide an overview of the EiE curriculum along with an in-depth examination of one EiE unit they would implement in the Fall 2013. All four teachers are employed in schools with large percentages of non-White students and students receiving free or reduced lunch. We deliberately chose to work with schools with diverse student populations with the goal of providing an opportunity to enact innovative, engineering-based curricula in hopes of challenging the status quo in a non-dominant demographic elementary school population.

Each teacher implemented one EiE unit during Fall 2013. The fourth-grade teachers chose the *Solid as a Rock: Replicating an Artifact* (see http://www.eie.org/content/rocks) unit with a focus on materials engineering. The fifth-grade teachers chose to implement *Now You're Cooking: Designing Solar Ovens* (see http://www.eie.org/content/energy) with a focus on green engineering. Teachers chose units because they best aligned with district pacing guides and relevant content standards. During the professional development, teachers engaged in and planned the EiE units with their grade-level peers and the research team. These collaborations continued after the summer session ended through use of a team blog, email collaboration, a team meeting during the fall semester and a team meeting in Spring 2014.

Our methods included semi-structured teacher pre- and post-implementation interviews (n=2 per teacher), student post-implementation interviews (n=70), lesson debriefing interviews with teachers, and classroom observations of all lessons implemented during each teacher's unit. These multiple data sources provided us with information about how the meanings of what/who counts as "smart" gets produced in practice in each classroom.

The focus of the pre-implementation teacher interviews was to understand their typical science teaching practices, their ongoing understandings of and experiences with engineering practices and the EiE curriculum, and to ascertain their goals and expectations for the unit implementation. Additionally, we asked teachers to highlight their expectations for student performance prior to implementation. Teachers identified two students from their classroom rosters they thought would be very successful with the curriculum, two students they were unsure about, and two students they thought would struggle with the curriculum. Once students were selected from the roster, we asked teachers to elaborate on why each student was selected and to identify qualities they felt would help or hinder their success. Establishing teachers' conceptions of students' competence in the regular science classroom prior to implementation and their rationale for choosing students serves as a comparison point in the post-implementation interview for the cultural production of smart in an engineering context.

The post-implementation teacher interview consisted of a similar line of questioning to get at the teachers' and students' experiences with the engineering curriculum. We asked teachers about their perceptions of students' successes and difficulties during the unit in light of student learning and engagement. Teachers were asked to reflect on any surprises or unexpected outcomes during implementation. Additionally, we wanted to understand teachers' perceptions of possible unique affordances of the engineering unit regarding students' performances, engagement, and learning. Thus, we asked them to make comparisons of *typical* student classroom engagement with learning and performances during the EiE unit.

Our student interview protocol, administered at the end of the unit, was guided by Carlone's approach[7; 10; 11] for capturing group-level meanings (cultural productions) by probing students' understandings of the norms in which they were held accountable to be considered "good" and "smart" participants and their affiliation with what it meant to be a "good" and "smart" participant. Questions elicited their definitions of the "smartest" engineers and "smartest" students, their self-positioning in relation to the students they identified as "smart", and their meanings of key engineering practices in the unit (e.g., making good choices, learning from failure, and being creative). In keeping with an ethnographic research tradition, we were most concerned about capturing students' and teachers' *local* meaning of "smart engineer" (i.e., the meaning produced by participation in classroom practices during the EiE unit) and the accessibility of that meaning for a broad range of students versus trying to assess their affiliation with engineering as a field or potential career. This approach is consistent with Lottero-Perdue and Brickhouse's study[12] of the cultural (local) definitions of "competence" attributed to employees at a technical company called W.L. Gore & Associates.

We attempted to hold brief check-in interviews with the teachers immediately following the lessons, however this occurred infrequently due to the rigorous demands of the teachers' schedules during the instructional day. The purpose of the check-ins was to get at teachers' emerging conceptions of student performance (e.g. *Who struggled today? Who seems to be 'getting it' today?*). Their answers also gave us information about what they meant by "struggling" and "getting it".

We conducted classroom observations in all settings for each day of implementation for a total of approximately 50-60 hours of observational time. Implementation of the entire unit took teachers anywhere from eight to twelve days to complete. The teachers had to be creative with their time to allow for all four lesson components: the engineering story; a broad view of an engineering field; use of scientific data to inform engineering design; and the engineering design challenge. Some teachers integrated the multicultural engineering story that set the context for the engineering unit into their English/Language Arts (ELA) time. We recorded detailed field notes, completed contact summary forms, and obtained audio recordings of students (only for those with parent permission and IRB approval) working in their cooperative groups for each session. The audio recordings and observations provided information about the group culture, student agency, positioning, and power differentials that took place during the course of the unit.

We are using Spradley's[13] semantic structure analysis to analyze data because this method is designed to capture categories of cultural meaning[11]. Interviews will be transcribed and subsequently coded using Dedoose qualitative software. Spradley's semantic structure analysis provides opportunities for us to examine our field notes and contact summary sheets for patterns that emerge from the enactment of the engineering unit and the cultural production of "smartness". The process begins with domain analysis as a method of searching for categories of culturally produced meanings of "smart" utilizing for example, *kinds of student questions*, *performances* or *reasons for becoming frustrated* as potential semantic relationships. These relationships can be further explored for patterns, categorical re-sorting, and particular attributes as we progress through Spradley's iterative steps of analysis including taxonomic and componential analyses.

The interview data, once transcribed, will also be analyzed for patterns and emerging themes. We are using Dedoose qualitative software for coding the interview data. Use of Dedoose can provide opportunities for advanced conceptual models and report development adding to the sophistication of analysis. For this work-in-progress paper, we made an initial pass through our data to report preliminary results.

Preliminary Results

Students were often initially predicted as being either potentially successful or challenged in the EiE unit according to their academic labels of giftedness, Academically Gifted or AG status or exceptionally challenged (EC) status. Before implementation teachers anticipated that institutionally-defined smart (gifted) students would fare best because they are "really focused", "good critical thinkers", "analytical", "on top of things", and "just go with it". They predicted that students who would struggle were those who were "inattentive", have "difficulty making connections", and were "slow processors". Their preliminary ideas left open the possibility for students' engagement to surprise them.

One of the most striking initial findings was that many students in all research settings identified "smart engineers" in their class differently (more broadly) than they defined "smart students" (those students who were smart in normal school activities), an indication that engineering has the potential to disrupt status quo cultural meanings of "smart". When they identified the "smart engineers" among their peers, they included a mix of AG students, general education students, and EC students. Their descriptions of what counted as smart were not confined to traditional notions such as getting good grades and having the right answers. First, we asked students to list the three smartest engineers in class and to describe the qualities that those individuals possessed that made them smart in engineering. We reminded students that they could include themselves in the list. Smart engineers, they said, "took their time and went over stuff" and chose the right materials for the design ("they put smart stuff into their ovens"). Students recognized that having "great" and "original" ideas with regard to the choice of materials incorporated into their solar oven designs made someone a smart engineer. Further, they noted that making improvements on their designs and using data from the control solar oven as a quality of a smart engineer. One student remarked that smart engineers "had the materials that made the sun want to shine on the box". Another student that named himself as a smart engineer in the rock unit characterized his smart qualities this way: "we took the time and thought about the properties of the materials" and “[we] all have different ideas and think above and beyond; [think] outside the box” in designing their artifacts.

These broader descriptions of “smart engineers” from their class stand in contrast to their descriptions of the “smart students” who do well in school all the time which, more frequently, fell along traditional lines. For instance, students indicated a smart student in class was “good at multiplication facts”; “works fast”; “pays attention”; “gets good grades”; and they are often members of the academically gifted program.

One of the fourth-grade teacher post-implementation interviews also revealed possible disruptions of classroom status, student positioning, and conceptions of smartness. Through our regular classroom presence, the research team noted one student grouping had a strong leader at its helm. Jackson (a pseudonym) was the voice of authority in his group; others looked to him for direction, and he was the person who had the final word in which direction the group would take. During the post implementation interview, the fourth-grade teacher was asked to reflect on her initial list of students and to note any potential surprises. Through deeper probing, Jackson’s performances came to the forefront. As observers, we had witnessed strong leadership qualities in Jackson; he exhibited a command for scientific and engineering details. Our acknowledgements and observations surprised Jackson’s teacher in her reflection, based on his previous classroom performances.

> Yeah, I can’t believe I forgot about him. Yeah, he uh, doesn’t have a lot of self-confidence [in regular class], doesn’t like to ask questions because he thinks that makes him look stupid. I actually have a system set up with him where he has to write a question on an index card and slip it to me. (Post-implementation interview 12-12-13)

Jackson clearly took on a new “smart” persona in his group during the engineering unit with no hint of his previous classroom insecurities. He also spoke out in their last day of implementation round-table discussion offering suggestions for future improvements in the unit, surprisingly in front of all of his classroom peers.

In addition to transformations in Jackson’s classroom positioning and performances, another female student (identified as AG and potentially successful on initial teacher interview) who reflected that she regularly struggles with social anxiety was able to assume a different role in her group where she had to “deal with a lot of arguments at our table” but, in the end, found resolution once she was able to “explain her reasoning” and achieved a more stable dynamic with another strong personality in her group. It appears this particular female student was similarly able to take on a new student position in her EiE group, much like Jackson was able to realize. Finally, in the same class the teacher noted a second female student, initially listed as being questionable in her potential performance with the EiE unit in the pre-implementation interview, who ended up challenging prototypical meanings of “smart student”.

> She was just able to explain things to me and really took an interest in it…the conversations and the overall level of thinking that I was getting from her, I was like, “holy cow!” because a lot of stuff doesn’t make sense to her. She struggles in the regular classroom. But, just to hear her back there having conversations with [an AG student in

> her group], you just don't see that in reading and math or anything else! (Post-implementation interview 12-12-13)

It appears that there were many surprises in this one classroom with regard to student performances and the cultural production of "smartness". Deeper examination of the overall culture of each classroom is warranted, as this particular classroom had a strong collective, supportive dynamic that may have contributed to the positive transformations that were witnessed. We believe that further time spent analyzing the data will reveal additional transformations and shifts in what counts as smart in the science classroom, as well as constraints in challenging the status quo meanings of smart, through the implementation of principles of engineering in the elementary school.

References

1. Varelas, M., Kane, J. M., & Wylie, C. D. (2011). Young African American children's representations of self, science, and school: Making sense of difference. *Science Education, 95(5),* 824-851.
2. Carlone, H. B., Scott, C. M., & Lowder, C. (In Press). Becoming (less) scientific: A longitudinal study of students' identity work from elementary to middle school science. *Journal of Research in Science Teaching.*
3. Carlone, H. B., Webb, A., Archer, L., & Taylor, M. (In Preparation). What kind of a boy does science? A critical perspective on the science trajectories of four scientifically talented boys.
4. Cunningham, C. M., Lachapelle, C. P., & Hertel, J. (2012). Research and evaluation results for the Engineering is Elementary project: An executive summary of the first eight years. Boston, MA: Museum of Science.
5. National Academy of Engineering. (2008). *Changing the conversation: Messages for improving public understanding of engineering*. Washington, DC: The National Academies Press.
6. Tonso, K. L. (2006). Student engineers and engineer identity: Campus engineer identities as figured world. *Cultural Studies of Science Education, 1,* 237–307.
7. Carlone, H. B. (2004). The cultural production of science in reform-based physics: Girls' access, participation, and resistance. *Journal of Research in Science Teaching, 41(4),* 392-414.
8. Carlone, H. B., Johnson, A., & Eisenhart, M. E. (2014). Cultural perspectives in science education. In S. K. Abell & N. Lederman (Eds.). *Handbook of research on science education* (2nd edition) (pp: 651-670). New York, NY: Routledge, Taylor & Francis.
9. Cunningham, C. M., & Lachapelle, C. P. (In Press). Designing engineering experiences to engage all students. In J. Strobel, S. Purzer, M. Cardella (Eds.), *Engineering in precollege settings: Research in practice*. Sense Publishers: Rotterdam.
10. Carlone, H. B., Haun-Frank, J., & Webb, A. (2011). Assessing equity beyond knowledge- and skills-based outcomes: A comparative ethnography of two fourth-grade reform-based science classrooms. *Journal of Research in Science Teaching*, *48*(5), 459–485.
11. Carlone, H. B. (2012). Methodological considerations for studying students' identities in school science: An anthropological approach. In M. Varelas (Ed). *Identity construction and science education research: Learning, teaching, and being in multiple contexts*, (pp. 9-26). Sense Publishers: Rotterdam, The Netherlands.
12. Lottero-Perdue, P. S., & Brickhouse, N. W. (2002). Learning on the job: The acquisition of scientific competence. *Science Education*, *86*(6), 756-782.
13. Spradley, J. P. (1980). *Participant observation.* New York: Holt, Rinehart, and Winston.