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The Work of Normative Case Studies in the Next Generation Science Standards (Fundamental)

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Introduction

The development and adoption of educational policy is a normative practice, one that reflects dominant assumptions about what counts as good learning and effective teaching, and about what kinds of citizens schools *should* produce (Beyer, 2002; Gaudelli, 2013; Luke, 2011; Zeidler & Sadler, 2009). The Next Generation Science Standards (NGSS), released in 2013, adopted by 15 states and the District of Columbia, with more states considering adoption (Heitin, 2015), offer important insights into culturally shared beliefs that connect both science and engineering education to workplace success. NGSS, in fact, names eight "science and engineering practices" it considers essential elements of K-12 education "based on an analysis of what professional scientists and engineers do" (NGSS, Appendix F). The analyses in this paper grapple with these necessary questions about culturally shared beliefs surrounding the role of both science and engineering in United States society.

Though NGSS is, by definition, a set of science standards, it makes numerous links to engineering education within its *Framework for K-12 Science Education* and throughout its standards and appendices (NRC, 2012). NGSS describes the blending of science and engineering as its first "conceptual shift," combining the two into "Science and Engineering Practices" (NGSS, Appendix A). NGSS explains, "This integration is achieved by raising engineering design to the same level as scientific inquiry in classroom instruction when teaching science disciplines at all levels and by giving core ideas of engineering and technology the same status as those in other major science disciplines" (NGSS, Appendix A).

The following analysis examines how it addresses issues of equity and access in the implementation of these "science and engineering practices." To do this, the authors:

1. Examine the historical purposes of science and engineering education (as well as the connections between science and engineering),

2. Provide a theoretical framework for examining the framing of science and engineering education in the NGSS, and
3. Analyze a case study (which contains both text and video footage) that NGSS provides for teachers of "economically disadvantaged" students.

As a work-in-progress, this paper begins with an in-depth examination of one NGSS case study and draws on heavily on Appendix D of NGSS (though the authors take the NGSS Framework as a whole, including other appendices, into account). This case study was particularly compelling to examine because 44 percent of children in the United States currently live in low-income households (Jiang et al, 2015). Thus, the claims that this case study makes are applicable to a significant population of students and educators. Further, this case study is relevant to engineering education in that it centers around a classroom that is engaged in "application of scientific knowledge to an engineering problem," and NGSS frames this case study as an example of its "vision of blending disciplinary core ideas, scientific and engineering practices, and crosscutting concepts."

Throughout this paper the authors examine and reflect on the purposes of science and engineering education as well as the ways in which large-scale science reforms (such as NGSS) attempt to address issues of access and equity that continue to persist in science and engineering education. In future, the authors hope to analyze other NGSS case studies and corresponding appendices to better understand how NGSS frames issues of equity in STEM education.

Background

Science and engineering education as an economic good

> *"Today's modern workforce depends on individuals with scientific and technological skills (NRC 2010; NSB 2010). Research shows, however, that we are not preparing all students to achieve high levels of science performance (USDOE 2011); we are failing to graduate enough students with the skills needed to fill the growing number of jobs in science, technology, engineering,*

and mathematics (STEM) (NRC 2010); and many members of our society do not command the scientific literacy necessary to address important societal issues and concerns (NCES 2010).”
-National Science Teachers Association, Position Statement on NGSS

For the better part of a century, policymakers, scientists, businesses, and the media have presented both science and engineering education as necessary because of its links to economic production that many perceive as vital to a functioning economy. To some, science and engineering helped to ensure the health of our economy, with well-trained factory workers to sustain the Industrial Revolution (Mann, 1914). To others, science education will continue to ensure that our economy functions well in the future, with employees equipped with the latest “21st century” technology skills (PCAST, 2010) that will help keep America “competitive.”

The National Research Council has commissioned and published reports (e.g., NRC, 2005; 2011; 2012) that place education (in general) and science and engineering education (in particular) in the context of similar economic outcomes. In these reports, it is common to read words and phrases like “economy,” “workforce,” “consumers,” “our nation's competiveness,” and “success” that justify this emphasis of STEM (science, engineering, technology, and mathematics) education. Academic conferences devoted to research on science and engineering education often have titles such as, “Making Value for Society” (American Society for Engineering Education, 2015) or “Raising the Stakes in Science” (National Science Teachers Association, 2016). Words such as “value” and “stakes” help reinforce an ideal of science and engineering education in terms of a common, economic good.

Entangled within the conversation about “our nation's competitiveness” is a discussion of equity within science and engineering education. The conversation surrounding equity in science and engineering seems to also point towards the economy. In fact, the National Research Council

(2011) states directly, “Providing all students with access to quality education in the STEM disciplines is important to our nation's competitiveness.” This framing is striking because it outright ignores larger, social explanations for why “all students” might not currently have access to “quality education in the STEM disciplines.”

In its position statement on the Next Generation Science Standards, the National Science Teachers Association (NSTA) also makes the economic purposes of science and engineering central, promoting “high levels of science performance” that will presumably allow more students to participate in science-related jobs that comprise “today's modern workforce.” Furthermore, the NSTA emphasizes “individuals” as the ones who possess the skills and knowledge required for these jobs. These individualist notions of success help perpetuate a meritocratic perspective about how a capitalist economy should (and does, according to some) function: that any individual who has the “right” skills (in this case, science knowledge or engineering skills) and works hard enough (in this case, in a science or engineering-related field) will be - and indeed, *deserves* to be - economically successful. According to this perspective, all of this will, in turn, help America's economy as a whole. This interpretation of science and engineering education in terms of its economic function pervades our society and academia far beyond the NRC and NSTA, as STEM careers and innovations within the field are considered vital to sustaining the health of our economy. The Next Generation Science Standards addresses the purpose of science and engineering education and grapple with how to support teachers in their effort to engage “all students” with these standards.

Equity in science and engineering education?

In recent decades, there has been significant criticism from academia and popular media (Lemke, 2001) of science as an enterprise, namely because of underrepresentation in science-related fields among many groups, including women, minorities, and persons with disabilities (NSF, 2013). This underrepresentation spans into the field of engineering, with women earning just 18 percent African-Americans earning a mere 4 percent, and Latinos earning just under 9 percent of all bachelor's degrees in engineering in the United States in 2011 (Yoder, 2011). Despite this, engineering education is framed largely positively, and often as something that is beneficial and necessary for society. It is easy to make this justification for both science and engineering as societal goods (rather than purely economic goods), particularly when science and engineering are often linked to solving complex environmental or health-related crises. However, the question regarding underrepresentation persists as a concern within science and engineering.

One way to address this concern is to consider how, particularly at the K-12 level, schools can ensure that "all students" have access to high-quality science and engineering education. This includes providing educators adequate resources to engage all of their students in science and engineering activities. The Next Generation Science Standards acknowledges this underrepresentation and devotes and entire appendix to case studies that it claims provide "strategies classroom teachers can use to ensure that the NGSS are accessible to all students" (NGSS, Appendix D). The authors selected the case study of "economically disadvantaged" students for further analysis.

The authors examined this case, in particular, because the lesson within this case study is one that NGSS describes as an "application of scientific knowledge to an engineering problem" (NGSS, Appendix D). The case study specifically lists "engineering design" as a performance standard for the lesson. Additionally, the case study praises the teacher for successfully engaging the class in an "engineering problem" and presenting "engineering practices" to the class as well as making connections to youth backgrounds and sense of place.

Theoretical Perspectives

In this paper, the authors call into question culturally shared beliefs about the role of science and engineering education in our society. Through frameworks of policy design theory (Schneider & Ingram, 1997; Schneider & Sidney, 2009) and critical discourse analysis (Fairclough, 2011; Lazar, 2005; Van Dijk, 1993), the authors critically examine Appendix D of NGSS: "All Standards, All Students" and its case study of "economically disadvantaged students."

Why policy design theory?

Policy design theory (Schneider & Ingram, 1997; Schneider & Sidney, 2009) helps us understand that policies do not simply emerge arbitrarily. Rather, policies are emergent in, and in turn contribute to, current political and social processes. In order to design a policy that "works" (in the sense that it becomes part of political and social processes), target populations must be considered and even constructed. This means that those constructing policy have to account for which groups of people they believe will most likely be influenced by the policy itself. Furthermore, this perspective helps us understand the groundswell of support for NGSS from educators, district leaders, curriculum designers, businesses, and even researchers.

The reason for considering policy design in the context of NGSS is that it provides a basis from which to understand how groups, such as those presented in Appendix D (i.e., "economically disadvantaged," "girls," "students with disabilities," "race and ethnicity," etc.), might have been constructed. It also gives us leverage to understand the historical context in which NGSS is situated and helps us critique NGSS without necessarily assuming that either its

Framework for K-12 Education or Appendix D ("All Standards, All Students") were created for either nefarious or disingenuous purposes.

Why critical discourse analysis?

Critical discourse analysis (Fairclough, 2011) provides a method with which to interpret and contrast the written text (contained in the case study) and the spoken text (contained in the video data from the case study). Using CDA as a methodological tool, we can consider the ways in which target populations (constructed through the process of policy design) are discussed and presented to educators in Appendix D.

In this sense, policy design is a way of understanding some of the underlying reasons why a policy might consider a particular group, while CDA aims to reveal the consequences of constructing this group (paying close attention to language). This means that CDA is concerned with the sorts of power dynamics at play in both the framing of issues and the naming of groups of individuals impacted by those issues.

Taken together, policy design theory and critical discourse analysis are tools that provide the basis for an analysis considers Appendix D in light of both NGSS and STEM education as a whole.

Why Appendix D?

Appendix D of NGSS is devoted to providing guidance on equity issues in science education, presenting principles for working with diverse learners. According to NGSS, "diverse learners" includes the four accountability groups defined in No Child Left Behind (NCLB) Act of 2001 and the reauthorized Elementary and Secondary Education Act [ESEA], Section 1111(b)(2)(C)(v):

- economically disadvantaged students,
- students from major racial and ethnic groups,
- students with disabilities, and
- students with limited English proficiency. (p. 2)

Appendix D focuses on three additional groups: Girls, students in alternative education programs, and gifted and talented students. Appendix D devotes a chapter to each these seven groups, interweaving a case study that draws from research conducted in formal classrooms with instructional principles for working with students from each group. In these case studies, NGSS communicates messages about each population it chose to identify. This analysis focuses primarily on one case study, "Economically disadvantaged students."

Methods

This paper investigates how "economically disadvantaged" youth are positioned in Next Generation Science Standards, in order to better understand how NGSS frames equity issues in STEM education. To do this, the authors examined the text, images, and video data NGSS used in the case study presented in Appendix D, alongside the NGSS *Framework for K-12 Education* itself. The text used in this analysis comes directly from the NGSS website, where there are also links to classroom video data that are used to construct each case study. The authors viewed each video associated with the "economically disadvantaged" case study and compared the information contained in the video to the information presented in the transcript.

Using critical discourse analysis as a framework, the authors identified moments (either in the examined texts or video footage) both in which the teacher positioned students and in which NGSS positions students. Within the video footage, moments in which the teacher reframes student ideas or asks students questions about their thinking were central to the analysis. The authors then put these findings into conversation with Appendix D, NGSS's transcript of the case study, and NGSS as a whole. This provided a way of making sense of how language from the classroom is reported in a policy document. It also generated more questions about how this relates to a larger conversation about how NGSS frames equity in STEM education.

In crafting this case study, the authors found that NGSS, within the text of this case study, both plays into and invokes images prevalent within our culture and in schooling about low-income youth. These include perceptions that low-income youth live in dirty neighborhoods (for example, neighborhoods that might be littered with "smashed cans"), and that their science-related concerns are (and perhaps should be) connected to pollution and transforming their neighborhoods from "dirty" to "clean." These images and discourses have implications for both social construction and identity, particularly when there is a mismatch between the case studies NGSS publishes and its intended audiences. Despite evidence to suggest that low-income youth might engage with their local environment differently from wealthier youth (Strife & Downey, 2009), there is no reason to believe that environmental concerns are (or should be) on the top of their science and engineering-related interests. As other studies have shown (Aschbacher, 2009; Barton & Tan, 2010), science and engineering interests among low-income youth span a range of topics and genres.

In addition to text and video interpretation and analysis of the case study itself, the authors considered how both science and engineering education are presented within NGSS's *Framework for K-12 Science Education*. Finally, the authors scrutinized additional texts (such as reports from the National Research Council and the National Science Foundation), websites, scholarly articles, and popular media to understand how NGSS fits within common cultural constructions of the purposes and goals of science and engineering education.

Findings

The Appendix D case study designed to assist teachers of “economically disadvantaged students” is presented as a vignette. This means that it is not a full transcript of the associated video footage that the authors viewed for comparative purposes. The vignette summarizes one teacher's lesson plans that NGSS presents as exemplary for its attention to student “culture,” “sense of place,” and “funds of knowledge.” The vignette specifically calls out several instances, which allege to embody the kind of cultural sensitivity necessary for working with “economically disadvantaged” students.

The authors of this case study are careful to point out that the vignette “is intended to illustrate specific contexts. It is not meant to imply that students fit solely into one demographic subgroup, but rather it is intended to illustrate practical strategies to engage all students in the NGSS.” While this seems to indicate some kind of recognition of the possibility of intersectionality, it plays directly into stereotypes often associated with "economically disadvantaged" students. Moreover, this vignette consistently implies that it was constructed from “real” data (even stating, “Therefore the writers have chosen to portray this vignette as originally recorded...”). However, in viewing the original video footage, the authors found that the vignette and the video data do *not* correspond. The vignette that NGSS provides states the following:

> *“Ms. S. moved over to another group that had just broken into laughter and asked what was so funny.*

Rick related, 'I see smashed cans all the time. I think an airfoot stomped the tanker down. And the molecules transformed into a molecule foot.'

Ms. S. asked, 'What is this imaginary foot?'

Latasia answered, 'Air.'

Ms. S. guided the students, 'Let's add that idea to the model.'

(The teacher validated the use of place [smashed cans in the neighborhood] to keep the students engaged and make a connection of science and neighborhood, an effective strategy.)"

The vignette above is constructed to make it appear as if Rick makes a connection to his neighborhood, and that the teacher then validates that connection, making "effective use of place to connect to students' experiences in their community." The video of this classroom exchange reveals, however, the following exchange:

"Teacher (Ms. S): If you have a water bottle or something, how do you get it to collapse?

Student 1: You just, like, take all the air out of it.

Student 2 (Rick): You shh- (makes motion of shaking a bottle)

Teacher: Okay. Or how else could you get it to collapse? I have a can in front of me or what-what can I do make it crush?

Student 2: (stomps foot)
Teacher: Yeah (points at student). You stomp on it! So, there, what are you doing when you stomp on it?

Student 2 (Rick): so it's like air feet! (laughs)

Teacher: So maybe there's something going on outside of it that's making it get smaller.

Student 2 (Rick): Yeah, it's like an invisible foot-an invisible foot out of molecules, and basically just stomped on it."

What emerges from the above transcription is that Rick was not the person who introduced the concept of "smashed cans," nor did he make any comment about seeing such items in his neighborhood. Instead, the teacher introduces the entire concept. Perhaps it is the case that Rick, or another student in this class, did make a comment about crushed cans (or a similar one), and the authors of this case study - in an effort to create a composite case study - wrongly attributed the exchange to this group. However, the vignette itself claims to be presented as "originally recorded," and there seems to be no evidence to support this claim.

This vignette also misinterprets place-based education in its link between "economically-disadvantaged students" and the presence of "smashed cans" in the neighborhoods of those students. These kinds of associations serve to reproduce common cultural images of low-income youth, rather than facilitate connections between students and their communities. If, indeed (as the video footage and case study both seem to demonstrate) this exchange is fabricated, what does this reveal about NGSS's understanding of the target population they constructed in their case studies?

Coupled with the additional finding that NGSS chooses to frame this case study within the context of science education as an economic good, this seems to make sense. Its entire approach to equity rests upon students from their seven case studies eventually having the ability to contribute, as individuals, to the economy of the United States. This makes it seem even more significant, especially from a policy design perspective, that NGSS receives both political and financial support from a multitude of large corporations including Dupont, Comcast, Microsoft, and IBM (which are listed on NGSS's website as either partners or sponsors of NGSS).

Analysis

> *"The discourse of poverty is often framed by limited resources and problems in need of fixing. While these realities are part of the education landscape, they focus on deficits – what youth and their teachers and schools are lacking."*
> *-NGSS, Appendix D*

The pressing issue with the construction of this target population ("economically disadvantaged students") is that writers did not portray the vignette as originally recorded. In viewing the original video footage, it becomes evident that Rick did not introduce the "place-based" connection that this vignette and case study celebrate. This is why framing matters here. In this case study, NGSS foregrounds place-based education on the grounds that it helps support economically disadvantaged students by "connecting science education to students' sense of 'place' as physical, historical, and sociocultural dimensions" and through "applying students' funds of knowledge and cultural practices."

This case study then takes a second opportunity to highlight the alleged "cultural context of the soda can" as an effective use of place to connect to students' experiences in their community." Even the choice of using the word "related" to describe Rick's apparently nonexistent description of the process is misguided ("*Rick related, "I see smashed cans all the time...'")*, as it suggests that the student was making a real connection between his life and what was happening in the classroom.

This means that NGSS has constructed a target population that does not seem to reflect actual humans, but rather composites of stereotypes that NGSS invokes (rather than the direct dialogue of the teacher or the students in the case study). "Economically disadvantaged" students are those who are likely see trash in their neighborhoods. And, within the context of NGSS as a whole, "economically disadvantaged" students are constructed as people who need an opportunity to make it in the world. Science and engineering (specifically, this set standards, concepts, and practices) is here to provide that opportunity. This assumes that schools that properly implement NGSS will also help solve the crisis of poverty in the meantime. While NGSS might have good intentions for "economically-disadvantaged students," it also highlights the dangers of what Ng & Rury (2006) describe as "well-intentioned efforts to educate poor children by disregarding the larger social context in which they live and are expected to succeed." This is further complicated by the fact that students almost certainly never belong to or identify with just one group.

Though NGSS is correct in saying that students can be members of multiple groups. it fails to highlight that there is a wide array of variation even within each group. The fact that this case study highlights invents an exchange in which "crushed cans" are described as an everyday element of an "economically disadvantaged" student's life also shows the essentializing nature of this case study. Given this sort of framing of science and construction of cultural categories of students, what is a classroom teacher supposed to make of these case studies? How useful or problematic is a case study that has been edited to fit the very specific construction of "economically disadvantaged" the authors of NGSS imagined?

Frames within this case study

Frame analysis (Goffman, 1974) provides a way to make sense of particular issues, situations, or ideologies based on how they are communicated among members of society. These frames do not reflect an objective "truth" about an issue, but instead reveal taken-for-granted societal interpretations of those issues. Within NGSS's case of "economically disadvantaged students," the authors found evidence of the following frames:

- Frame 1: Science and engineering for the economic good
- Frame 2: Science and engineering as a way to alleviate poverty
- Frame 3: Science and engineering as an individualistic pursuit that alleviates poverty and contributes to the greater economic good.

An examination of framing in this case study, NGSS as a whole, and other national education and science and engineering education organizations reveal the first frame, which is "science and engineering education for the economic good." This term is appropriate because it highlights the main purpose for which science and engineering education appears to exist. Not only do major for-profit corporations publicly support and fund NGSS, but testing companies (such as Pearson and McGraw-Hill) and other private educational corporations that produce curricular materials also frame science and engineering education this way.

This falls in line with the sorts of neoliberal ideals that first pervaded education during the 1950s (where it was taken up in the context of the Cold War and the fight against communism), through *A Nation at Risk* in the 1980s (where it was taken up in terms of America's perceived global competitiveness), and again in the early 2000s when President George W. Bush signed No Child Left Behind (where it was taken up in terms of an individual child's ability to compete in the marketplace). Over time, each new layer of neoliberal ideals ultimately helped to culturally reinforce the frame of "science education for the economic good." Alongside this frame rest the second frame ("science and engineering as a way to alleviate poverty") and a third, related frame ("science and engineering as an individualistic pursuit that alleviates poverty and contributes to the greater economic good.")

In using words like "individual" and consistently highlighting that the workforce needs (or even "demands") individuals with particular skills, it is easy to see how the second and third frames are intertwined with the first. Under this framing, an individual's ability to compete within a capitalist marketplace rests upon access to a high-quality science and engineering education. This means that it makes sense to identify a target population as "economically disadvantaged." It also makes sense to construct these individuals as people who might live in run-down neighborhoods, littered with "smashed cans." This framing certainly puts NGSS in a position to be able to help any "individual" who might have previously been denied access to science and engineering education in the past. It also means that, as long as NGSS provides case studies such as these, there are few excuses for “individuals” who are not able to participate in the field of science and engineering. With each of these frames in mind, we can re-examine Appendix D and better answer questions about how target populations come to exist and later inform both policy design and its implications.

Implications

Appendix D has implications for students, teachers, and schools. Identifying and defining populations of students informs the types of discourses that exist within the seven case studies of Appendix D. One explanation for targeting “economically disadvantaged” students is that their performance on standardized tests (often described as “low” or “underperforming”) has consequences for students, teachers, schools, school districts, and states. However, this case study is framed in terms of *opportunities* for “economically disadvantaged” students.

When it comes to economically disadvantaged students, however, it seems that “opportunity” refers to opportunities to participate in the economy. Though the vignette purports to present “real classroom experiences of NGSS implementation with diverse student groups,” it falls short of this claim. Beyond the vignette's loose interpretation of “real classroom experiences,” the vignette allows for a shallow interpretation of the concepts of “funds of knowledge" and "place-based education.” Moll et al (1992) describe “funds of knowledge” as cultural knowledge and aspects of a student's home life that students bring to classroom. To claim that this is present anywhere in this vignette seems to miss the mark.

So then, what difference does it make whether Rick introduced the concept of “crushed cans” or not? Beyond the ethics of research, this case study matters because the entire argument for the relevance and importance of the “crushed can” metaphor rests on Rick himself introducing the concept. If he is not the one who introduces this, no longer is this an example of a student making a connection to place, and no longer is it accurate to assume that this student is drawing on funds of knowledge. This is particularly significant because NGSS provides Appendix D as a resource for teachers working with specific groups of students (at times, representing backgrounds different from the teacher), most of which have been historically underrepresented in science and engineering.

Another implication is that this entire case study underscores the everyday issues that economically disadvantaged students (who come from a range of diverse backgrounds and geographic settings) might face and bring with them to the classroom. This case rests on the ideal that students engaged in high-quality science and engineering instruction will automatically be streamlined into a competitive economy in which they will be able to break free from the shackles of poverty. Nowhere does it discuss the day-to-day challenges of economically disadvantaged students, or the immense power that rests in having connections to certain high-paying employment opportunities (Armstrong & Hamilton, 2013). Thus, relying on NGSS appendices alone does provide teachers with adequate support to engage "all students" in ways that might support their further pursuit of science and engineering-related interests or careers.

Conclusions

What are the purposes of science and engineering education? According to NGSS, economic competitiveness and individual success are as two of the major reasons why all of the United States *should* adopt the Next Generations Science Standards. Moreover, these two reasons seem to suggest these are the reasons why "economically disadvantaged" students, in particular, should do science and engineering. This framing makes sense for those who ultimately believe that high-quality science and engineering education will make our society better, particularly learned science and engineering skills can be applied in a way that both solves problems and maintains the healthy functioning of our economy. In this sense, there are "moral politics" (Lakoff, 2002) at stake here. We can especially see how framing science and engineering education in terms of economic gain makes sense within particular worldviews, in particular the kinds of worldviews that place emphasis on the individual. What NGSS presents in Appendix D (and throughout its *Framework for K-12 Science Education*) indexes greater beliefs that pervade our society, and it points towards larger questions we might have about how to address issues in science and engineering education.

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