The Typical and Ideal Engineer, As Seen by Our Students

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ABSTRACT

It is unfortunately a well-established fact that females and minorities are underrepresented in science, technology, engineering, and mathematics; this trend holds true for construction engineering also. This raises equity and inclusion issues regarding learning and identification and questions about who students are obligated to be in a setting and who students are becoming in a setting. Considering the context of technical work in relation to engineering identities, such as the attributes of the Engineer of 2020, engineering and engineers are positioned as making a difference in the world. This has implications for re-shaping students' developing engineering identities in ways that have potential for attracting a wider pool of students to the discipline. As part of a larger project that explores this relationship, this paper is a first step in exploring students' perceptions of engineering identity. In our analysis, we found that students described the typical engineer as a problem solver, analytical, smart, and humanitarian; and described their personal ideal of an engineer as humanitarian, smart, respectable, involved, and organized. This knowledge is the first step towards enabling construction educators to frame disciplinary content in ways that support inclusion of the construction student body and profession.

INTRODUCTION

Females and minorities are underrepresented in science, technology, engineering, and mathematics. For example, Yoder (2015) shows that the representation of females in the field of engineering varies from 49.7% in environmental engineering to 10% in construction management engineering.

As a byproduct of extant social structures, interaction patterns, and unexamined stereotypes that systematically disadvantage females and minorities (NAS, NAE, and IOM, 2007), these low diversity figures present a problem for the engineering industry, which depends upon a well-trained and knowledgeable workforce. As part of meeting this need, engineering educators described the Engineer of 2020 as someone with strong analytical skills, practical ingenuity, creativity, and good communication skills, as well as business and management skills, leadership abilities, high ethical standards, a strong sense of professional identity, flexibility, and being a lifelong learner. These attributes are seen as shaping engineering activities in relation to the positioning statement that "engineering and engineers can make a difference in the world" (NAE, 2008:11). Situating engineering work in these ways can be seen as changing perceptions of both the engineering profession and how the public understands engineering. It also highlights the social justice dimension inherent in engineering and its role in developing engineering identities that are juxtaposed to the normative and enduring attributes of a typical engineer. This has implications for re-shaping students' developing engineering identities in ways that are inclusive and thus have the potential for attracting a wider pool of students to the discipline.

LITERATURE REVIEW

Identities, as parts of self, take on and are shaped by our self-conceptions and the ways we are positioned by others (Bell, et al., 2012). As identities emerge in and are reflective of the enabling and constraining social structures, we draw predominantly from a sociocultural perspective to define and conceptualize identity. Nasir (2010:54) draws on Wenger's (1998) sociocultural perspective to define identity as "involving both an internal, coherent sense of self and the way in which one is positioned as one participates in a range of cultural and community practices. Thus, identity is related to belonging in particular communities and to the way that one makes meaning of that belonging." From Nasir's (2010) conceptions of identity, we see how identity, particularly identity in learning contexts, is tied to students' developing identities in a discipline. Additionally, participation in the practices of local communities, such as undergraduate engineering classroom communities, plays a role in the development of identities. From this perspective on learning and identity, Nasir maintains that learning includes experiences where values, norms, and perceptions of the past and future play a role in the kinds of activities one engages in, and what one has the opportunity to learn. This perspective, shared by Davies and Harré's (1990) Positioning theory, highlights the ways students are positioned and the ways students position themselves in the moment and over time across social practice. This cultural anthropological perspective conceptualizes identities as locally and interactionally constructed and shifting in relation to social settings and actors (Holland, et al., 1998; Nasir & Hand, 2008). From both sociocultural and cultural anthropological perspectives, we draw on Nasir and Hand's (2008:147) notion of identity as "practice-linked identities", which they describe as identities that one acquires, constructs, and embraces through participation in particular social and cultural practices. Practice-linked identities are differentially shaped by engagement with the enabling and constraining features of a practice.

Varelas (2012) states that an understanding of how practice-linked identities develop entails: (1) “Who are students obligated to be in a setting?” and (2) “Who are students becoming in a setting?” The questions posed by Varelas raise equity issues regarding learning and identification. Equitable learning opportunities enable access to content, concepts, and practices that should be conceived of as relating to a socially, situated developing self. Students’ practice-linked identities are thus considered in relation to the learning processes of being, becoming, knowing, and doing, which are constructed dialogically through engagement, emotion, intentionality, innovation, and solidarity (Petrich, Wilkinson & Bevan, 2013). Social structures create relations of alliance, dominance, or subordination, which influences participation, knowledge construction, emotions, and actions. One’s position in social structures is enabled or constrained by the arrangement of social and material resources. These resources reciprocally define and are defined by our positional and relational identities. The notion of self becomes essential for understanding how students develop practice-linked identities. In the context of social and material processes, the self is “enacted and negotiated in and through the self’s relations to [others]” (Thibault, 2004:15). The enabling and constraining social structures give path to reframing’s in actions and stances through the self-perspective. Thibault (2004) adds that a reframed self-perspective elaborates on our meaning systems which we draw on to guide our actions, anticipate possible courses of action, and evaluate from a self-perspective. Social and material resources reciprocally define and are defined by students’ positional and relational identities.

METHODS

Data Sources

Qualitative post-test data from an engineering identity questionnaire was used to identify students’ perceptions of how to be thought of as an engineer (Tonso, 2006).

Pre-test Data: Participants completed an engineering identity questionnaire related to (i) self-perceptions of engineering identity that has previously been used in STEM identity research (Chachra et al., 2008), and (ii) being thought of as an engineer (Tonso, 2006). Next, participants responded to an engineering problem framed either in a humanitarian context, an industrial context, or no context.

Post-test Data: Participants then engaged in a reflection activity followed by the engineering identity questionnaire described under ‘Pre-test Data’. The activities described were completed in a standalone session that took approximately 80 minutes.

For this paper, we report only on the post-test data, which includes student responses to how to be thought of as an engineer (Tonso, 2006). In order to highlight the ways students are positioned and the ways students position themselves in the moment and over time across social practice, we focus on the following questions: (1) *In your own words, please describe a typical engineer. What is this person like? What makes them an engineer?* (2) *In your own words, please describe YOUR PERSONAL IDEAL of an engineer. What would this person be like? What would make them your ideal?*

Participants

Participants (n=299) who took the engineering identity questionnaire come from different regions in the United States, including the North, the South, the Midwest, and the Rocky Mountain region. The average age was 21, ranging from 18 to 35 years old. In terms of the participants' class standing, 2% were freshman, 12% were sophomores, 36% were juniors, and 49% were seniors. There were 28% (n=84) of the participants identifying their sex as female and 70% (n=208) as male. The majors in which participants were enrolled in ranged from civil and/or environmental engineering and architectural engineering to construction management. While 78% of the participants indicated their race was White (including Middle Eastern), 10% identified as Asian (including Indian subcontinent and Philippines), and 3% identified as Black or African American (including African and Caribbean). This data is a subset of a larger dataset that will be collected and analyzed for a larger project.

Data Analysis

Qualitative Coding

The post-test questions related to how to be thought of as an engineer (Tonso, 2006) were transcribed into a Microsoft Excel spreadsheet and uploaded into Dedoose Version 8.2.27 (SocioCultural Research Consultants, Los Angeles, CA), software for analyzing qualitative data. Using an iterative, deductive approach, we used Litchfield and Javernick-Will's (2014) themes to code student responses.

The results reported in this paper are based on the percentage of students who indicated each theme in their response to one of the post-survey questions. I.e., the percentages were calculated by dividing the number of students with at least one response matching a theme by the total number of students who responded to the survey. No-answers or blanks were excluded from the analysis. Of the 299 students who took the survey, 262 and 271 responded to the questions related to a typical engineer and their ideal of an engineer respectively. Students who did not provide an answer to one of the post-survey questions were omitted from the analysis. For each theme, we derived a percentage of respondents, which allowed us to compare the codes within an individual question and across questions.

RESULTS

The Typical Engineer

For the first question, *In your own words, please describe a typical engineer. What is this person like? What makes them an engineer?* 88% (n=262) of the students responded. From within these response percentages, a typical engineer is primarily a "problem solver" (56%), "analytical" (38%), "smart" (31%), and "humanitarian" (27%).

Problem Solver: Student perceptions of a typical engineer as a problem solver are associated with the ability to solve complex problems. The ability to solve complex problems includes finding "*simple*", "*practical*", or "*best*" solutions. While a typical engineer is perceived positively at solving problems, responses also emphasized solving "*real world problems*" and providing solutions to "*humanity's problems*", as illustrated in the following response: "*Someone who solves a problem making the world they live in more efficient through careful problem solving.*" Student responses also highlight that a typical engineer is willing and motivated to "*tackle complicated* *problems*" that "*nobody else want to think about*". Responses also emphasize that a typical engineer can accomplish this because they "*enjoy problem solving*", they are "*diligent*", "*hardworking*", and have been "*trained to solve problems*", because they use "*their technical skills*", "*critical thinking*", and "*experience*". These assertions are illustrated by the following student response: "*They take that knowledge and apply it to the real world constrains to try and provide solutions to humanity's problems.*"

Analytical: The typical engineer is perceived as "*making the world they live in more efficient through careful problem solving*". This capacity to solve problems comes with having an "analytical" disposition. While student responses included attributes such as "*good at math*" and "*logical*", responses also included critical thinking and being "*technically savvy*". With "*a background in math & science*" and as "*someone who likes math and science*", a typical engineer is also perceived as being "*technical*" and someone who "*enjoys technical things*".

Smart: With an analytical disposition, a typical engineer is also perceived as being "smart". Student responses related to "smart" were framed as something that is generalizable. With the responses being framed as "*a typical engineer is smart*", this establishes and affords this notion of the typical engineer with a high degree of authority. Viewed as a norm, the responses construe "smart" as a quality that is a given for a typical engineer. In some cases, a typical engineer is smart because "*they have some sort of engineering degree*" and "*knows a lot of fancy words*". In other cases, student responses suggest a pushback on the notion of a typical engineer being smart. For one student, "smart" was reframed as follows: "A *stereotypical engineer is a smart uptight person who thinks they are better than most people. They enjoy math and are anti-social.*" While some of the responses are framed negatively, student perceptions of a typical engineer being smart are framed positively and as a given.

Humanitarian: While the typical engineer is perceived as a problem solver, analytical, and smart, student responses (27%) also characterize the typical engineer as "humanitarian". The responses that characterize the typical engineer as humanitarian encompass ways to help or promote human welfare. Responses are framed in relation to society, people, communities, and life. In terms of society, responses included "*ways to improve society*", "*to better the needs and wants of society*", "*contribute to the advancement of human society*", and as "*a person who cares deeply about the progress of society*". In terms of people, responses included "*help people*", "*bring joy to people*", "*impact people*", and "*engineers strive to improve the quality of life of the people around them.*"

Student responses also highlight the role of a typical engineer in relation to human welfare. For example, a student wrote "*that engineers have a duty to the people*". In terms of the community, the responses suggest a moral necessity – "*Do the right thing to the community*" – and obligations – "*A typical engineer is one who works for the community*." The role of a typical engineer gets positioned as a moral necessity that includes conditions of enforcement (i.e., duties) which are connected to power and control. Consequently, student responses are framed as obligations where the typical engineer has the authority over improving the quality of life, indicating a sense of duty. In summary, student responses are framed to improve the conditions of society, people, communities, and life in general. This theme persists in student responses related to their personal ideal of an engineer.

The Personal Ideal of an Engineer

For the second question, *In your own words, please describe YOUR PERSONAL IDEAL of an engineer. What would this person be like? What would make them your ideal?* 91% (n=271) of the students responded. Students' personal ideal of an engineer as "humanitarian" (44%), "smart" (38%), "respectable" (30%), "involved" (29%), and "organized" (28%).

Humanitarian: While 27% of the responses show that a typical engineer is perceived as humanitarian (as discussed in the previous section), 44% of the student responses show that their personal ideal of an engineer is "humanitarian". From the student responses, we find that their personal ideal of an engineer as humanitarian comes with being "*ethical*", "*kind*", concerned with "*safety*", "*caring*", "*compassionate*", and "*empathetic*". These attributes are in contrast to certain reasons for being an engineer. For example, "*The ideal engineer is someone that is not in it for the money and is doing their work."* From the responses, we find that economic and personal gains characterized by "*greed*", "*money*", and "*power*" are counter to being "*motivated by goodwill*". As one student wrote, such dispositions have negative implications for society: "*Engineers who cheat, kill people*."

Smart: The perception of an engineer being "smart" extends to students' personal ideals of an engineer. From the responses, 38% indicated "smart" and were again framed positively and as a given attribute. Other attributes that characterize "smart" include "*intelligent*", "*knowledgeable*", and "*technical expertise*" in their field of study. For the most part, we found that student responses indicated being smart generally *and* being smart in their field or in what they do. This is in contrast to the responses related to students' perceptions of a typical engineer being smart, where being smart was only generally framed.

Respectable: The notion of a moral necessity identified in student responses of a typical engineer as humanitarian extends to students' perceptions of their personal ideal of an engineer as being "respectable". From the responses, 30% use the attribute "respectable" when describing their personal ideal of an engineer. In relation to the notion of a moral necessity, student responses construe "respectable" as good or bad – for example, "*A person with a good moral compass*" – and right or wrong, as illustrated in the following student response: "*can be trusted to do the right thing*". The responses describe an engineer as "*a good person with morals*", as someone who is "*honest*" in terms of their character as well as work, "*humble*", and "*responsible*". These qualities suggest a moral necessity as further illustrated in the following student response: "*An engineer is a good person. I think more good people are needed in the world and it is ideal to have them.*" Being "respectable" is also associated with being "*responsible*", "*reliable*", and having professional "*integrity*". Accordingly, in terms of public regard, possessing such traits means being "*respected*", having a "*good reputation*" and being "*untethered by corruption*". Having professional "*integrity*" was also associated with being "*ethical*", "*considerate*", and as "*Someone who is patient, treats his workers equals with no superiority complex, but very strict*."

Involved: The attribute "involved" was also frequently included in students' personal ideals of an engineer; for example, "*Usually engineers aren't so good with communication, so when you meet someone who is, they stand out*." Counter to the stereotypical view that engineers are bad at communication and socially awkward, the student responses describe an ideal engineer as “a good communicator”. While being “*able to effectively communicate their ideas*”, engineers are also seen as “*a good listener*”. Being “involved” was also associated with having “*strong people skills*” and being “*sociable*”. Other responses were situated in the context of “*companies*” and related to projects with “*clients*” – for example, “*Very active with all other companies/workers that investing in this project.*”

Organized: From the student responses to their personal ideal of an engineer, the most frequently reported responses included “humanitarian”, “smart”, “respectable”, and “involved”. From these notable attributes, “organized” was another that stood out. Student responses included being “*efficient*”, considers “*technical and non-technical factors*”, “*thorough*”, and detail-orientated – “*an eye for detail*”.

DISCUSSION AND CONCLUSION

Student perceptions of a typical engineer, in relation to their personal ideal of an engineer, share these attributes: “problem solver”, “analytical”, “smart”, and “humanitarian.” When compared to the nine key attributes of the engineer of 2020 (NAE, 2004), we see students perceiving and identifying with the engineer of 2020.
From the response percentages, a typical engineer is primarily a “problem solver”, “analytical”, “smart”, and “humanitarian”. From these responses, a typical engineer is identified as “smart” and “humanitarian” and by the socio-material practices cast as roles that are valued: “problem solver” and “analytical”. The identified attributes of a typical engineer suggest having knowledge and an understanding of engineering work, the skills and relationships needed, as well as being responsible. In addition, Pawley (2009) provides accounts of faculty members talking about engineering in terms of problem solving, thus establishing a narrative that is “universalized” and that gets taken up by students as they report on their perceptions of a typical engineer.

While a typical engineer is perceived positively at solving problems, responses also emphasized solving “*real world problems*”, providing solutions to “*humanity’s problems*”, and being willing and motivated to “*tackle complicated problems*” that “*nobody else want to think about.*” Students ascribe these attributes in a humanitarian context where actions are interpreted as complex world problems. The engineer of 2020 is positioned as a problem solver that creates “offensive and defensive solutions at the macro- and microscales in preparation for possible dramatic changes in the world” (NAE, 2004:24). Tann (2010) states that categories generalize situated actions by individuals as general attributes of people in the category – “*engineers solve world problems*” and “*a typical engineer is smart*” – which then can be used to project further expectations of the categorized persons, including activities, obligations, rights and knowledge. The projected expectation of a typical engineer “*tackling complicated problems*” can be viewed in terms of complexity and in terms of how students are conceptualizing problem solving within a broad context.

The role of a typical engineer as “humanitarian” gets positioned as a moral necessity connected to power and control. Consequently, student responses are framed as obligations where the typical engineer has the authority over improving the quality of life, indicating a sense of duty. This perception is also a notable attribute for students’ personal ideals of an engineer, including “smart”, “respectable”, “involved”, and "organized". Identities can be categorized as they are connected to places, thus establishing expectations as a result of the socio-material arrangement; positioned in relation to the kinds of persons and one another (evaluations); and organized by actions and discursive stances as meaningfully linked concepts. The co-articulation between the different systems allows expectations to project moral obligations and positions to bundle as collections of attributes around expectations or categories. The interactions between these two aspects are managed through the constant foregrounding and backgrounding of information. The implications are that the way expectations or categories are formulated facilitates positioning. Consequently, identities are continually construed, enacted, and organized in discourse to represent a coherent framework of identities against the background of other changing identities – a typical engineer, their personal ideal of an engineer, the engineer of 2020. Tann (2010) explains that student affiliations in engineering are enhanced or reduced as students are positioned to recognize engineering knowledge and practices as their own, forming "a conceptual repertoire and a location for persons within the structure of rights for those that use that repertoire (Davies and Harré, 1990:46)."

Students' personal ideal of an engineer included "humanitarian", which is associated with a collection of attributes that include "*ethical*", "*kind*", concerned with "*safety*", "*caring*", "*compassionate*", and "*empathetic*". This collection of attributes positions students' personal ideals of an engineer into a "humanitarian" category, with expected attributes projecting moral obligations that include social responsibility and a culture of greater public engagement. While 44% reported "humanitarian" as a personal ideal, 27% reported "humanitarian" as an attribute of a typical engineer. "Involved" was also reported as an attribute for students' personal ideal of an engineer, which counters the stereotypical view that engineers are bad at communication and socially awkward. While student responses counter some stereotypical views, they also align with a normative engineering identity that is characterized by technical expertise in student responses to their personal ideal of an engineer as "smart" and organized." The socio-material arrangements and practices in settings categorize students based on their social acts where identities emerge as a related social phenomenon. Membership categories, such as "smart" and "organized", are relational when "articulated within the values set up within such structures." "Category-bound features," such as "humanitarian," "respectable" and "involved", allow students to establish categories and infer values associated with the categories. Thus, categorization, used as a positioning strategy, establishes an implicit division between "us" and "them" (Tann, 2010).

Students learn expectations about the behavior and responses of engineers as well as imitate, stereotype, or parody them. Lemke (2008) asserts that by acting and being like the typical engineer, students acquiring some attribute enables them to be engineers of particular kinds. Students may not identify with all the attributes of an engineer, as we saw in student responses to the typical engineer, but they acquire them over time and through sustained participation. Also, students may not have full, active competence in the full active sense of being an engineer, but they passively acquire it by being able to interpret the behaviors of an engineer for their purposes, as we saw in student responses about their personal ideal of an engineer.

Future work entails exploring how students feel they are similar to and different from these typical and ideal descriptions of an engineer. In addition, it involves "resolving the lack of fit" (Lemke, 2008:38) from both a gender and contextual perspective. The categorizations described by Tann (2010) are created as positions that students acquire and identify with. Such categorizations and positioning in relation to practices essentializes and politicizes identities. Studying how students' practice-linked identities can be re-categorized and re-positioned in relation to who students are obligated to be in a setting and who students are becoming in a setting makes visible the issues related to belonging, equity, and inclusion as they relate to identities and expertise.

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