How Writing for the Public Provides Affordances and Constraints in Enacting Expert Identity for Undergraduate Engineering Students

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The science communication field has recognized that the present media landscape is fractured and segmented with social media and online communities making up important spaces where audiences find their news and share opinions in ways that have become mainstream but not fitting conveniently within traditional forms of media (TV news, newspapers, and magazines[1, 2, 3]. This fractured and segmented landscape has been characterized as a challenge and an opportunity to engage the public in science by Trench[2], as well as other scholars who have explored using blogs, Twitter, podcasts, and various mediums to share their research with those outside of the field, finding in these mediums a direct point of contact with non-experts.

One internet-based genre of science communication that has received significant attention is that of blogs by scientists and science writers[4, 5, 6]. They are lauded as a method of "direct and spontaneous exchange" between experts and public audiences about recent research through interactive platforms[7] (p. 2). Through an analysis of science bloggers who promote and discuss scientific research, Luzon[8] notes that these writers use five main strategies to communicate with audiences outside of the field: a) take into consideration the background knowledge and information needs, b) selecting the most salient information from the research, c) appraise the results and significance of the research, d) speak conversationally and try to involve the reader, and e) include their personal opinions and feelings on the matter. Guiding Luzon's work is Hyland's concept of "proximity" which is how writers "represent not only themselves and their readers, but also their material in ways which are most likely to meet their readers' expectations" which sheds light on "how writers take their readers' likely objections, background knowledge, rhetorical expectations and reading purposes into account"[9] (p. 117). Proximity includes numerous rhetorical features that are negotiated between writer and audience, but particularly important to science communication is "tailoring information to the assumed knowledge base of potential readers," showing credibility, taking positions and evaluating topics, and engaging the reader by acknowledging the latter's presence[9, 8] (p. 434). Moreover, it is worth noting that links to Wikipedia entries are often used by science bloggers to give background information on topics, which is particularly important when writing for diverse audiences, or those with varying levels of expertise on the topic. While proximity has been used to analyze written texts, the concept could be used on other types of texts from YouTube videos to children's books and Wikipedia articles.

At the same time, in the education field, scholars have noted that young people are involved in creating, sharing, modifying, and consuming content in these spaces in a participatory manner[10]. Looking at the same fragmented media landscape, the opportunity that presents itself in terms of giving university science students chances to engage the public with science is that these students already make up the audiences and contribute to in various forms the spaces that scientists are

trying to reach. The low barriers to enter the space and make a blog or YouTube channel, their openness, and relative ease of use make them ideal platforms and genres in which science students can share their work and ideas. In other words, the challenges of blurred boundaries between those who produce content and consume it, the fragmented nature of the media landscape can be an opportunity for what Rhinegold[11] considers to be young people speaking for themselves on issues they find important in spaces they are already involved with.

In doing so, these writers are demonstrating their relationship and role, or positionality with their audiences by speaking, thinking, and acting[12] as scientists who are engaging in science communication. For example, when an undergraduate science major blogs or writes an essay to share on a social network about their current research and or their field, they are taking up the practices of scientists like Trench[2] and others, likely with limitations and in ways that need to be further examined.

While the science communication field continues to call for STEM undergraduate and graduate students to take part in practices associated with engaging the public with science, there is a paucity of programs that offer such experiences with real audiences[13, 14]. Baram-Tsabari and Lewenstein argue for these types of experiences to include hands-on components that develop the identity of students as those who value and practice public engagement. However, what shape such writing projects can take within engineering researcher programs and what evidence there is that they support these types of learning goals is an understudied area of scholarship in STEM. The current qualitative discourse analytic study explored what affordances and constraints, in terms of enacting the identity of an expert, a writing for public communication project offers undergraduates in a summer engineering research program. Specifically, we explored two research questions:

> RQ1: In what ways did the authors (undergraduate engineering students) position themselves as engineering researchers and engineers through their texts and with what degree of success?

> RQ2: To what extent did students value writing for the public?

Theoretical Framework

Historically, scientists have paid little attention to communicating about their work with public audiences[15], creating a sharp divide between "elite science and popular culture" (p. 240). This condition persists today; many scientists resist engaging with the public in favor of protecting the status of their disciplinary fields[16]. If scientists wish to enter into more dialogical, mutually beneficial communication with the public, then individual scientists or scientific collectives such as universities, research centers, or museums, must take part in public engagement, dialogue with publics in two-way communication[13, 3].

Recognition of new goals for public science communication (coupled with scientists' and science educators' struggles to meet them) has led to science and engineering communication studies[17, 18, 19] and a plethora of advice from scientists and communication scholars about how to write for the public[20]. Despite this interest, few university science or engineering programs dedicate formal coursework in public communication to undergraduate or graduate students[21]. When programs do offer such training, they are usually limited to teaching students to write in traditional genres such as press releases, newspaper-style articles, and essays[13, 14], and fail to consider more personal, informal, and affective forms of communication such as face-to-face conversations that can occur through science cafes or street science[22, 23] or to make use of multimedia genres such as podcasts, blogs, or vlogs[2].

Communicating with Publics in a Digital Age

The internet and digital technologies have created new opportunities for scientists to engage in dialogue with public audiences, for instance, through blogs or podcasts sharing and even promoting their recent and ongoing research[2]. "Blogs are windows into academic coffee room chatter of the sort the media is not normally privy to" (Tomlin 2007, personal blog). In the multimodal communication landscape of the 21st century[24] public communication requires scientists to develop literacies that go beyond writing that privileges alphabetic text to also include multimedia sources and genres. Here, we are concerned with "writing" writ large, broadly defined as including many different genres that go beyond texts composed of traditional alphabetic texts primarily, but that also include videos, podcasts, and other more visual mediums.

At the end of the 20th century, new "multiliteracies" communication practices emerged in relationship with new digital technologies, online media and the evolving economic and social landscape prompted by these dynamic changes[24]. The multiliteracies perspective called increasing attention to multiple modes of communication that extend beyond spoken and written text, to the way people also communicate through visual, gesture, auditory, and spatial modes[25, 26], for example in video games, Youtube videos, and infographics. Multiliteracies also called attention to how different communities, including scientific communities, use language practices to construct "some aspect of reality from a particular point of view, a particular angle, in terms of particular interests"[24] (p. 25). The 21st century multimodal landscape offers new opportunities to incorporate new forms of media and also to new literacy challenges for educating future scientists and engineers, for instance, inviting undergraduates to communicate not only technical, but also to create more affective resonance with public audiences through informal and affective forms of communication (Trench, 2008).

Implications for Engineering Education

Few academic programs offer scientists and engineers opportunities to grow in the practice of communicating with public audiences, and little scholarship exists on how to support such educational opportunities[13]. Students participating in "science communication activities in

authentic settings, creating written, oral and visual science messages suitable for various non-technical audiences, and engaging in fruitful dialogues with those audiences"[13] (p. 288). Reviewing articles that report on public science communication learning, Baram-Tsabari and Lewenstein[13] found that academic programs attend to goals ranging from "affective issues, content knowledge, methods, reflection, participation, and identity" (p. 285). Ideally, a science program gives students an opportunity to speak, think, and do as scientists and engineers with real audiences if they are to make inroads to attain these goals[12]. This means students and audiences negotiate roles and relationships, or positionality, through their interactions as the former make bids to be taken as a particular kind of person[27, 28,] in this case of this study, an engineering researcher communicating with non-experts. Brownell et al (2013) called for undergraduate and graduate science programs to include formal courses in writing for lay audiences and to communicate the value of such activity and scientists' responsibility to participate in such activity. In one notable exception, Imperial College London science students create podcasts as part of their academic programs[2].

Several barriers exist to such education becoming part of traditional engineering education programs. First, many current scientists (including engineering researchers) find it challenging to communicate with the public, having never learned such genres in their own scientific training[14]. Many academics do not value such communication practices and may even intentionally cultivate a "culture of exclusivity"[20] to avoid incurring negative perceptions of their work by other scientists. Finally, the tenure process in most universities provide little incentive to engage in public discourse, although this may be changing in universities where local and global public engagement is an explicit part of the institutions' goals. Some of these barriers can be met through education, some have to come through changing the culture of academia[20].

While traditional perceptions of public communication persist, there are still important reasons for engineering students to learn to use multiple mediums to communicate with the public. For one, self-promotion; it is becoming more common for research journals to invite or require authors of peer-reviewed work to write summaries for the public. For instance, authors accepted to PLOS journals are required to submit a non-technical summary of their work, and scientists' social media presence is increasingly recognized by university promotion and tenure committees[29]. Finally, there is an increased need for an informed and scientifically literate citizenship in democratic societies due to the grand challenges of the 21st century[24], and an increasing expectation for scientists and engineers to take responsibility for contributing to the scientific education of such a citizenry[17, 22,] and to knowledge dissemination and broad accessibility of scientific knowledge[3].

Method

Participants and Context

Fourteen diverse undergraduate students took part in an intensive summer program in photovoltaic (PV) solar energy engineering research at a large university in the southwestern US. In parallel with the lab research they conducted with their primary research mentors, participants took part in a writing project to share their knowledge of solar cell manufacturing and research with the public. The writing project was framed for participants as an opportunity to share what they are learning in the program and what they discover as researchers with wider audiences. The project was framed as asking REUs to follow in the footsteps of public scientists such as Neil deGrasse Tyson and Bill Nye as well as the writer Amanda Gefter who, as public intellectuals, write for audiences outside of academia[30]. REU's could write individually or in groups in a medium (video, music, newspaper article, etc.) of their choosing so that they can communicate in a way relevant to their daily lives and not require additional training to learn the genre. The writing project started with a facilitator introducing the project goals, followed two weeks later by an in-progress check in, a critique session with 9th grade students as an audience, and then a final deadline at which point the finished product should be posted or submitted online to an appropriate platform.

Challenged to communicate their new PV knowledge using a medium of their choice and to an audience of their choice, two students completed projects that involved contributing to Wikipedia articles, one wrote an essay for the social media platform Reddit, and two wrote a children's book on this topic; one wrote a pro-solar energy song, and two teams created videos for posting to YouTube.

All of these genres have in common that they are amenable to platforms widely accessible, require relatively few resources or time, have built-in communities, and are used widely. For instance, as a platform in which anyone can contribute to the growing body of knowledge, Wikipedia is supported by a community of users that curate and edit contributions that present specialist information in ways understandable to the general audience, in other words, a public discourse. Contributing to this public platform, students would be taking on the role of expert in this process[12]. Likewise, writing about engineering concepts in a narrative text, such as a children's book, also requires the students to recontextualize their specialist discourse but to a simpler discourse as it needs to be understandable to children. As a social media platform, Reddit poses an interesting challenge as it includes a mixture of specialist and public discourse, depending on the subreddit. One student chose to publish in a subreddit that can be characterized as leaning toward the latter as it was for industry experts and those interested in PV solar, but not necessarily for academic researchers. Thus, each communication platform offered its own unique affordances and challenges.

Data Sources and Analysis

Data for this study were collected across the ten weeks of the summer research experience program. The primary data sources were participants' finished, published public writing project artifacts, public response to those products, and post-program interviews in which participants

were asked to explain what they saw a the main differences in communicating with engineering audiences and the general public, and to identify audience they value more and why. Informal interactions between Author 1 and participants over Facebook probed for participants' reflections on how successful did they thought their project was and what response they received from their audience(s).

The student writing projects were analyzed using discourse analysis[12] and multimodal analysis[30, 31] in order to examine how the students enacted positions through roles and relationships visa vi the reader, and the extent to which they were successful in their positioning (RQ1).

We considered criteria for successful positioning in multiple ways. First, we asked ourselves whether the authors actually positioned themselves as engineering researchers or engineers - what were the strategies they use, and did they appropriately signal membership in that community. For instance, scientists are expected to use the language of uncertainty and to avoid overstating their claims when discussing the objectives and results of their work (e.g., Hyland, 2010). Therefore, we examined each project artifact for how it used uncertainty markers. Also, each study participant was also a mentee in the research labs to which they were apprenticed. This positionality may have curtailed their likelihood of positioning themselves also as engineering researchers or engineers. We wondered whether and to what extent these apprentices would dually position themselves, given their novice status. Second, we analyzed how and to what extent each writing project used the norms of the community that was its intended audience. In other words, did they utilize the "correct" tone, .. Did they include elements common to writers of the genre? Did they constrain themselves to these accepted/acceptable/normative elements and structures? Further, did they use the practices expected of community members contributing to the platform/medium to which they were posting?

We also examined the response of public audience members as further evidence of success. Positionality is a relational construct; one cannot enact a positionality alone, but must rely on others taking up your bids for particular positions[12]. Thus, we analyzed response (and lack of response) from the community as a signal of each participant's success.

Interviews were coded through thematic analysis[33] (RQ2) to identify relationships between participants' characterizations of how they valued communicating with the public, and their relative valuing of this engineering communication practice in comparison to communicating with expert audiences.

Findings

This section first reports on findings related to RQ1, students' success in positioning themselves as engineers through their public writing projects. We then turn attention to findings related to

RQ2, explaining the themes related to students' valuing of communicating with the public that arose through our analytic process

Students Positioning Themselves as Engineering Researchers (RQ1)

Data analysis led us to see that the public writing projects on informational and narrative texts allowed students to position themselves to varying degrees of success as experts of engineering research and PV solar manufacturing. They approached the task in many ways, choosing various communication mediums, platforms, and audiences. Thus, in the section below, we discuss findings for RQ 1 in relation to three categories of writing projects: (a) Wikipedia edits and Reddit posts, (b) YouTube videos, and (c) artistic renderings.

Contributing to web ecologies: Wikipedia Edits & Reddit posts. Three REU students chose to contribute writing projects for the online platforms, Reddit and Wikipedia. All three of these students discursively took positions of authority and recontextualized engineering discourse into public discourse, and used academic talk moves, such as hedging, to express degrees of certainty in regards to what the scientific community "knows" at present.

Wikipedia Edits

For the two participants who used Wikipedia to look for opportunities to communicate their research to the larger public, they contributed to existing Wiki articles and submitted these changes for approval by moderators. In both cases, participants added texts about the current research as they relate to concepts fundamental to their research projects. In addition one added explanations of equations for current and voltage.

Participant 1 makes many rhetorical moves characteristic of scientists as she makes hedging statements (Hunston & Thompson, 2001; Myers, 2003) and indicates degrees of uncertainty based on on the current limits of what is known and potential directions for research. For example, she uses statements like "It is not currently known… It is believed… It is not known…" Her role is to explain concepts in a step by step fashion, positioning the reader as a person lacking knowledge but capable of understanding the information if it is presented clearly. She does not insert herself into the actions of the research, but rather as a passive reporter of current conditions and as an educator to the reader by using an analytical process rather than a narrative as she explains the parts to explain the whole. Moreover, the topic is framed as an engineering problem about finding practical and efficient materials, rather than questions of pure science, and by extension positions herself as an engineer researcher finding these answers to contribute to a growing body of knowledge which the readers would then "discover" at a later time.

Likewise, Participant 2 positions engineering researchers as fine tuning and improving efficiencies. However, she does so through a narrative representation with the scientific community having agency, taking action through verbs such as "looking," "optimize,"

"achieve," and "found." The narrative begins with a research intention and ends with success, conveying a positive image for science and characterizing progress as a matter of "varying" or trying different combinations and parameters of existing materials, thereby tinkering their way to success. This includes less hedging than in Participant 1's wiki edits, as it focuses on the positives rather than the limitations of what scientists, and by extension themselves, are doing in PV solar research.

In both cases of the Wiki edits, participants positioned themselves as engineering researchers through their two slightly different characterizations of what the scientific community is doing and how they do it. In addition they cite journal articles to support their facts, which is both a writing convention of scientific discourse and valued in the Wikipedia community. Both participants can both be seen as successful in the sense that moderators initially accepted their edits to the respective Wiki pages. However, seven months later, a moderator edited Participant 1's edit, shortening and making it more concise by deleting some of the explanations that she had given for the concepts. The moderator stated that the entry had too much speculation and uncited claims. However, the altered version still retained her hedging and limitations on the current knowledge and put back one of the sources. This would be a good example of a platform and its community of users policing itself, either accepting, rejecting, or editing contributions based on its standards and practices. In other words, an online community that reads and edits a student's contributions should be taken as a response and a kind of acceptance of the student's bid to be authorities on the topic and speak as members of the engineering researcher community. Without a reaction, we are less able to determine whether or not or to what degree positionality has been established in a real social situation as opposed to a researcher's approximation of what meaning is conveyed through the text.

Reddit Post.

Unlike Wikipedia, Reddit's content is not limited to a single genre and it is in many ways meant to be a space for commenting and discussing content posted directly to the platform as well as found elsewhere on the Internet. One participant wrote an essay and posted it to a subreddit, or forum, on the PV solar industry and research. He sets out to inform redditors about important aspects of solar cell manufacturing and in the process explaining his role as an intern in a university laboratory where he is mentored by scientists. He inserts himself directly into the text affiliating himself with the scientific community which is a positioning that Wiki articles do not allow. He characterizes himself as a participant in the research and "helping" making solar cells more viable and efficient, again positioning himself as a kind of engineering researcher in a direct fashion, but not making claims to being a full scientist. Moreover, the participant's rhetorical strategy and grammatical structure assumes that the reader is not informed and is in need of an education on PV solar technology.

As a platform for linking, sharing, and discussing internet content, success on Reddit can be judged in terms of how many likes and comments a post receives. After six months, the

participant's post had zero up votes and only one comment, which expressed encouragement for the participant's internship. This minimal response indicates that the participant's bid to be taken as a PV solar expert and kind of engineering scientist by the subreddit to be not very successful. Among the possible factors leading to this is that members of that subreddit most often link news articles, blog posts, and other content as a post rather than an entire essay written by oneself. It was not deleted by moderators, but it does not follow the conventions of this community.

YouTube Channels

One four-person group and one individual participant, Participant 3, made YouTube channels with a series of videos that set out to convey the fundamentals of PV solar technology, and in the latter case, how it relates to his research project. In a similar vein as Participant 2's characterization of researcher in her Wiki article, they make bids to position themselves as kinds of engineering researchers; however, with the more numerous semiotic resources available to the medium, such as numerous visual elements (perspective angle, color, shape, motion), and gesture to accomplish this. Moreover, both the group and the individual participant chose genres of science video presentation, humorous-youthful science presenter and tutorial, that placed noticeable constraints to their strategies in making bids to be taken as engineering scientists by YouTube viewers. In the case of Participant 3's videos, he uses an overhead camera angle on a blank screen in which he places hand-made graphics and diagrams and draws out labels and other graphics while he narrates. This is a Khan-academy style video presentation that is direct and personable while still granting authority to the presenter on the topic. Conversely, the group took the approach of humorous and youthful science presenters in the style of Bill Nye the Science Guy, having presenters explain concepts through narration and graphics on a whiteboard. In both cases, the participants make a claim of expertise in the field PV solar engineering, displaying their knowledge, and position the viewer as in need of an education in the fundamental concepts and processes of solar cells, how they work, and how they are manufactured. They often stop to explain technical terms that come from the field, recontextualizing the social language into everyday terms through examples and metaphors. The YouTube creators used this rhetorical move far more than the authors of the Wiki edits projects, presumably because of the limitations of the Wiki genre, which emphasizes concise, information focused texts and does not leave room for such descriptions and elaborations and use of language.

Within Participant 3's narrative, he is able to assert his identity as an engineering researcher through presenting himself as a researcher and exhibiting how scientists think and their values. In the first video, when he introduces his research project, he states, "this is the research I am currently doing" which is more direct than the Wiki edits that did not allow persons to put themselves into the text. Moreover, he states "One of the most important things in research is exploring every path possible" indicating what he himself does as a researcher. This meta-communication about the nature of research also implicitly suggests membership in the

community of researchers, as only members are likely to step outside of the field to reflect in this way. Moreover, Participant 3 uses the rhetorical strategy of scientific argumentation in the way he supports his claims with facts, in a way explaining to the audience how to interpret that fact. This positioning of the audience as lacking of knowledge is remarkably exhibited when he uses intertextuality, or embedding other texts or statements within his own statement, in order to anticipate the questions the audience. For example he says, "Sheet resistance?.. but wait. What's sheet resistance?" speaking in the voice of the audience, thereby further positioning the audience as lacking and needing knowledge.

Although both groups had their channels viewable by the public, they received a small number of views, many of which were by members of the PV solar program and friends and family. In this way their degree of success in positioning themselves as engineering researchers would be considered low by the lack of response from audiences. So in effect, we see there to be potential for them to be taken as scientist engineers by virtue of the way in which they used semiotic resources to convey their message(s), but without a response we cannot be certain. This is the case for all of the proceeding participants' projects as they did not include actual audiences outside of their peers.

Artistic Renderings

Children's Book. As a work of fiction aimed at grade school children, Sammy the Silicon Wafer is a children's book that positions its audience and writer in a unique way. It tells a tale of transformation in which a plain silicon wafer becomes a useful solar cell that is "going to save the earth!" using everyday verbal and visual metaphors to convey a vicarious experience for its young readers to go through the many steps of the PV solar cell manufacturing process. The narration takes the reader in hand as a companion to the main character who passively follows what the scientists tell it to do. Sammy follows orders and takes their explanations unquestioningly much like a teacher-student or parent-child relationship, which infers a similar authority-subordinate relationship between the writers and readers. The story also uses the knowledge of the scientific community intertextually. However, whereas the Wiki projects cite journal articles to support their statements, Sammy indirectly quotes what scientists say, which is the child equivalent of "My mom says…" in that the words of an authority figure are sufficient support for something to be taken as the truth. In this project, the scientific community and its work is depicted in engineering terms and in a glowingly positive light. In these ways, the two authors have made a bid to be taken as a kind of engineer and scientist as they build the fictional world in which they position themselves as solving the world's problems through mass producing solar cells and a source of judgement and knowledge on the topics.

Folk Song. Unlike the other projects examined in this study, the folk song "Solar Song" is not a bid directly or indirectly by its author to be taken as an engineering researcher. Rather, performing the song and its lyrics conveys a close relationship with the audience even if he is a kind of expert who is not necessarily a part of the scientific community. Through folksy

articulations, the song sounds and reads like an early Bob Dylan protest song as it implores the audience to pay attention to the environmental problems facing the world and the possibilities that solar energy present. It uses collective pronouns like "us," "we," and "our" in one sense positioning the singer with the audience in that they are together in this predicament while scientists are others doing important work in understanding the world. Then in later verses, he describes sunlight in scientific terms with lyrics like "energy packets," demonstrating a degree of expertise on the topic. The genre of the folk song is in many ways antithetical to establishment identities and institutions, which carries over into this project and would normally place the participant at odds with the very source of his authority. However, the participant manages to make a bid as an expert-messenger, a knowledgeable person who recognizes the value of science but does not identify with it.

Student Valuing of Writing for the Public (RQ2)

Science education tends to forefront communication with other scientists, and/or industry members - when science communication is considered at all. Quite rare are engineering education programs that attend to communicating with the public as a valued communicative literacy for novice scientists. However, believing in the value of such practices ourselves, we were curious as to the extent to which participants in this study valued writing for the public.

Analysis of post-project interviews indicated that students overall found communicating with the public to be a worthwhile endeavor and an important part of their experience in the program (RQ2). They largely perceived their project as meaningful and they believed communicating with the public a valuable practice. When explicitly asked which they valued more, communicating with the public or communicating with engineers, participants' responses were mixed. Half said they valued the former more, at least at this point in time as undergraduates. Three valued communicating with engineers and scientists more and another three said they valued them both equally. Of those that valued communicating with the public more offered various reasons, some explaining that it was important to be able to talk to family and friends about their work as a source of support. This personal use of science communication was not anticipated by researchers, however, it resonated with some participants in the study. Another participant pointed out that if the public "[understands] the benefit of using solar, then all of our problems are solved," placing the importance on educating not just their immediate social circle, but society at large for a social good. A third opinion of note pointed to the possibility that contributing to the available knowledge online would also aid scientists who need to work in other fields and science students such as herself who could not find enough additional resources to help her learn the PV solar material at the start of the program.

The three participants who valued communicating with scientists and PV engineering audiences more expressed that at this point in their career, establishing themselves among professionals and focusing on their education was a higher priority than communicating with the public. One felt

they are still learning to write like a scientist. Another explained it this way in a follow up text answer:

> I'm not interested in continuing to share [my project] because that would mean that I want attention. With people seeing it, they might want me to continue doing [more], but I'm not interested in doing that. I have too much coming up...If I am not well versed in the field, then I can't divide my attention towards spreading awareness and in trying to do so, would only make my time management inefficient and I am not interested in losing time haha. A college kid definitely cannot waste time!

Note that this participant considered engaging the public as a considerable time commitment as well as his concern that he has not established himself enough in the field to do so in in his opinion.

Of the three participants who valued both equally, one explained, "You can't put a value on either. Your family and friends you go home to. You want them to care and support you. Your professional support you spend your life there… You need to be respected there. They are both important." Here she has combined the importance of being able to include personal relationships with her work life while at the same time needing to be able to communicate effectively with other PV engineering professionals.

From these interviews, valuing themes coalesced around the importance of using science communication as a form of personal communication to explain what they do professionally to family and friends as well as inform the public to create interest in and knowledge about PV solar as a social good. The latter is valued because it influences government funding support and indirectly oneself as researchers. In addition, one participant who did not indicate valuing one audience more than the other, indicated that talking with people who were educated but not necessarily scientists was an opportunity to be asked questions he did not think to ask about his own work and found new insights from the conversations. Unexpectedly, one participant who did not feel confident in his own understanding of PV solar concepts felt more comfortable talking to those outside of his field about his work. Moreover, other participants expressed nervousness communicating with the public because of their feeling of a lack of knowledge on the topic. At the same time, for some participants, talking with the public provided a sense of comfort and an opportunity to contribute, i.e., create interest, in PV Solar.

Overall, almost all participants placed communicating with the public in high esteem, finding various situations in which it was useful to themselves for personal, professional, and/or societal needs. The largest differences lie at what point in time in their career and what priority to place on such an endeavor. They have present demands and aspirations that either make being able to talk with those outside of the field about their research more or less important at the moment.

Discussion

Our discussion is organized in relation to the two research questions. We first discuss insights that arose through our analysis of the ways participants positioned themselves as engineering researchers through their respective genre and to what degree they were successful at this through their writing for the public projects, before turning our attention to new insights related to valuing communicating for the public.

Unique positionings

One thing that struck us while working with the data for this study was the range of positionings taken up by participants across the projects: as scientist, as intern, engineer, as a community member distanced from the scientific community, and to an audience of children. For each genre, we noticed unique methods the authors used to position themselves. The authors of both Wiki projects were the only participants to explicitly cite published research, even including specific references, as is the convention for this platform. Both of the YouTube video projects presented multiple visual supports of information, including static models of elements and dynamic models representing processes associated with the research described.

The only other project to incorporate any visual imagery was the children's story, which incorporated color as a semiotic resource to a much richer degree than the Youtube authors. The children's story was also the only project that used fiction and position the audience as children. Another interesting uniqueness in this project was that the main character is a kid being socialized to be a solar cell, just as the readers are being socialized into becoming knowledgeable and supportive of solar energy, thereby creating a vicarious experience for the assumed-child readers (Evans, in progress). This is an interesting twist on the usual child-scientist relationship in that scientists are distant, distinct holders of knowledge typical of children's media (Bell, 2007; 2008), however, in the case of Sammy, engineering solutions, processes, and goals are the focus and means by which the main character, and by extension the child reader, has meaningful impact in the world. This sidelines the attention to "discovery" and pushing the boundaries of science which typically appear in this genre, opening a door for authors to position themselves as not only as scientists, but engineers, through their text.

The song was the only project whose primary purpose was persuasion rather than information dissemination. Moreover, this was the only project in which the author positioned themselves with the audience, (as opposed to across from the audience), as a member of the community. Finally, the author of the Reddit article was the only participant to explicitly present themselves as a research mentee, and was the project containing the most auto-biographical information. While this is a strategy typical of scientist engaging the public through Web 2.0 platforms (Luzon, 2014), posting an entire essay into the subreddit is not consistent with that particular online community's practices.

We argue that these positionings were not solely due to platform, but also to genre. While Wikipedia only uses fact-based, encyclopedic entries, YouTube and Reddit contain multiple

genres of content. One can imagine a children's story, documentary, or steampunk-themed animation told through a YouTube video, although none of our participants chose to create such a video.

Insights Related to Valuing

The question of the extent to which participants valued their experience in writing for the public is an interesting one, give that wide breadth of knowledge (or lack of) and perspectives on this topic among practicing scientists and engineers. The participants in our study did express valuing the activity of writing for the public, as well as valuing of writing for science and engineering audiences. For both public and expert audiences, there is an anxiety and nervousness; some participants felt more anxious talking to the public, one expressed feeling more anxious talking to engineers. In both cases, this nervousness was tied to feeling a lack of knowledge. At the same time, for some of the participants, talking with the public provided a sense of comfort, seeming to act as a respite from the intellectual and emotional demands of. Further, other participants viewed writing for the public as an opportunity to contribute, i.e., to create interest in the field for those currently outside of it. For participants adopted this goal, their valuing of that goal was sufficient to promote engagement in the activity.

As a second issue related to valuing, we wish to point out that the participants who created the YouTube videos had to invest considerably more time and effort to design and create their project than the other participant. That this would be required of such a project did not come as a surprise to the participants who purposefully chose this pathway. Rather, they intentionally chose this genre and platform because they valued its affordances for the audiences they wished to engage.

As a final point related to valuing, we observed that all participants chose genres and/or platforms that were personally familiar and that they valued, using them in their own life. Further, they selected their content thoughtfully, with audience needs in mind.

Implications

The findings from this study suggest implications for public communicative platforms and recommendations for giving undergraduate science and engineering students opportunities to take part in science communication practices. The activity does seem to be promoting valuing of scientists communicating with the public. However, we see limitations in this enactment of the design of the innovation. The enacted writing for the public activity may have pointed participants toward communicating with the public as a teaching activity in that they saw their role only as disseminators of knowledge and educating uninformed audiences as their primary purpose in writing for the public. While this is appropriate for contributing to Wikipedia entries, it would seem rather limiting in the dialogic sense if audiences are not expected to contribute to the conversation or have anything for the scientist to learn from. Although this might be due to a

limitation of the research design i.e., something about the interview questions might have prompted these kinds of responses, we think it more likely points toward a conception held by many, if not all of the participants.

In a future iteration of this writing project, students would first be exposed to multiple science communication models, such as dialogue and participatory, in addition to the dissemination model[3]. Moreover, students need to keep in mind that each website (and at time genre) has its own community with norms, values, and practices of its own. They should be encouraged to explore to understand the lay of the land of the space in which they want to engage with audiences if they are to expect audiences to respond to their creative works. However, it should be noted that in many cases like YouTube and Twitter, it can take considerable time and effort to establish a following and may be beyond the scope of a single writing project. Finding opportunities for students to interact with authentic audiences continues to be a challenge for science communication training.

Finally, another important consideration is that undergraduate science majors may not feel ready at this stage of their career to be experts in the eye of the public. A tension exists between their confidence in their disciplinary knowledge and being put on the spot to give accurate information in a particular moment on a specific topic, whether that audience is other experts or non-experts. Moreover, students have many competing priorities with their studies and may find writing for the public one thing too many to juggle, perhaps because or in spite of doing the project within an intensive program. This raises the possibility that some experiences in science communication are more appropriate at the graduate level than undergraduate. At the same time, the internet affords a degree of anonymity and chances for individuals to try on new identities[10, 34] in a low stakes context that might mitigate student reticence at being a scientist and engineer in the public, especially when that public is a virtual public. Further research is needed to clarify reasonable expectations and to guide future iterations of this and similar instructional activities aimed at helping novice engineering students enact the richest engineering identities possible.

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