

Robots vs Animals: establishing a culture of public engagement and female role modelling in engineering higher education.

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Abstract

A widespread culture supporting public engagement activities in higher education is desirable but difficult to establish. Drawing on social cognitive theory, this science communication project aimed to enhance culture change in engineering by developing communication skillsets of early career engineers, particularly supporting female engineers as role models. Engineers received training in storytelling to present at live events, enhanced by peer group social persuasion and vicarious modelling. A science communication coordinator and senior management endorsement removed barriers to participation. Evaluation showed engineers' self-efficacy levels significantly increased. Qualitative data highlighted a developing culture of engagement but purposive selection of women proved controversial.

Running Head

Robots vs Animals: establishing a culture of public engagement within engineering

Key Words

Public engagement, organizational culture, role models, women in STEM, engineering

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Introduction

While numerous funding and policy drivers exist to support public engagement (PE) with science, technology, engineering and mathematics (STEM) (Burchell, Franklin, & Holden, 2009; Palmer & Schibeci, 2012), there is little evidence of widespread culture change enabling or incentivizing academics at higher education institutions to undertake PE with a variety of audiences (Dudo, 2012; Grand, Davies, Holliman, & Adams, 2015; Neresini & Burchi, 2011; TNS, 2015). Prior research has indicated that organizational culture is critical to enable PE activities, with support needed within management and organizational structures (France, Cridge, & Fogg-Rogers, 2015). In parallel to this issue, a long-standing aim for PE activities has been to encourage more girls and women to choose STEM careers. Women already working in STEM have been identified as key role models to demonstrate the accessibility of STEM careers for future generations of girls (Buck, Plano Clark, Leslie-Pelecky, Lu, & Cerda-Lizarraga, 2008). To explore how these parallel outcomes can be produced, this paper describes the development and testing of an organizational model of PE within an engineering research laboratory, with a particular focus on female role models given the emphasis on recruiting female students into engineering.

Public engagement and organisational culture

The format and terms of PE are much debated; within this paper we draw on the typology developed by Rowe & Frewer (2005) which outlines three purposes of PE: public communication, public consultation and public participation. While recognizing the differences between “engagement” as a two-way process and the “public understanding of science” as a one-way process, in practice, we assert that it is difficult to distinguish among the many interactions that occur over time between a research laboratory and wider publics. Indeed, previous research has indicated that UK science communication practitioners interchangeably (even if incorrectly) use the terms “education outreach,” “science communication,” “informal science learning” and “public engagement” (Illingworth, Redfern, Millington, & Gray, 2015). We argue that different activities may have different purposes and audiences, but over time this generates an overarching “ecosystem” of PE in a research environment, with staff supporting colleagues and building on previous interactions (Fogg-Rogers, Bay, Burgess, & Purdy, 2015; France et al., 2015). It is this ecosystem, or “culture,” of PE that we sought to study and influence in this project.

Numerous surveys have indicated that scientists and engineers view PE activities as volunteer work which are additional to their main academic responsibilities (Andrews, Weaver, Hanley, Shamatha, & Melton, 2005; Bauer & Jensen, 2011; Besley & Nisbet, 2011). The majority (61%) of 1558 UK STEM researchers surveyed in 2015 indicated that PE activities are seen as detracting from competing

demands on their time for research and career progression (TNS, 2015). The PE activities surveyed included giving a public lecture, participating in public dialogue/debates, working with schools, working with museums, and engaging in cultural performances or the entertainment industry. The majority of researchers surveyed (71%) had not received any training for these activities (TNS, 2015). Several studies have explored which factors predict participation in science communication and PE activities. Discipline is critical, with physicists more likely to view participation as a threat to personal reputation, while biologists are more likely to view it as part of their role (Ecklund, James, & Lincoln, 2012; Johnson, Ecklund, & Lincoln, 2014). Gender is also influential with men more likely to take part in media interviews (Crettaz von Roten, 2011), while women are more likely to take part in PE activities with children (Johnson et al., 2014). Career stage is also a factor, with Bauer and Jensen (2011) indicating that senior academics undertake most PE. Surveys of scientists active in PE have indicated that a personal commitment to the public good, professional obligation, and feelings of enjoyment and personal efficacy are strong predictors for participation (Besley, Oh, & Nisbet, 2013; Martin-Sempere, Garzon-Garcia, & Rey-Rocha, 2008).

Beyond these personal identifiers, decisions at an organizational level have also been found to be influential; indeed, allocated workload time was the most cited factor (at 48%) by scientists surveyed in the UK deemed to increase PE activity (TNS, 2015). Similarly, professional communication training (Trench & Miller, 2012) and administrative support from science communication coordinators have been cited as beneficial for researchers (France et al., 2015). Furthermore, visible supportive leadership (France et al., 2015) and descriptive norms (whether scientists believe their colleagues participate) (Dudo, 2013; Marcinkowski, Kohring, Fürst, & Friedrichsmeier, 2014; Poliakoff & Webb, 2007) have all been implicated in generating an organizational culture of PE activity, that is, an environment where PE activities are considered a normal and beneficial thing for STEM researchers to do.

Perceived self-efficacy for engagement

Participation in PE activities therefore appears to be affected by both individual capabilities and beliefs and also by the normative beliefs and support networks in an organisation. In order to influence these factors in a science communication context, we have drawn on a psychological theory that is used to influence both individual and cultural behavior change. Social cognitive theory provides much insight into the mechanisms behind these factors, indicating that an individual's learning is not only related to their personal capabilities and experience, but also to their observations of others within the context of social interactions, experiences, and outside media influences (Bandura, 2001, 2004). In other words, an individual will not perform a behavior just because they

have mastered it; they may or may not replicate this behavior depending on the outcome of the behavior and how others react to it socially (Bandura, 1976, 1977, 2001).

As the author of this theory, Bandura (1977) developed a way to measure these varied influences on an individual through their perceived self-efficacy (PSE). PSE is a measure of an individual's belief in their own capabilities to produce specific actions, and it reflects a perception of capability rather than measuring actual performance (Bandura, Barbaranelli, Caprara, & Pastorelli, 2008). PSE is specific to each domain of activity (Bandura, 2006), so while STEM researchers may have high PSE for communicating their subject knowledge with fellow academics, they may have low PSE for undertaking PE activities with wider publics. This is important, as despite many funding and policy drivers urging more PE activity, the literature reviewed above indicates that scientists and engineers need to feel that PE activities and behaviors are worth performing in order to do it; social and cultural influences are critical in this respect.

Research into self-efficacy indicates that while PSE is innately determined by natural capabilities to some extent (Declerck, Boone, & De Brabander, 2006), it can be influenced and improved. A critical way to improve PSE is through successful direct learning experiences. This mastery over a task encompasses experiencing a successful personal performance with an accompanying positive emotional arousal (Bandura, 1998); this may be why training and supportive starter programs in PE are helpful. Alongside this, experiencing social persuasion through peer approval or coercion validates that the behavior is normative and worthwhile (Anderson & Betz, 2001; Bandura, 1998); that is, researchers need to receive a reward or recognition in some form from their peers or leaders in order to keep doing PE activities.

Indirect learning experiences are also useful to improve PSE; these are derived from vicarious modelling - watching others perform the activity successfully (Bandura, 2004). This is important for women in STEM, and is otherwise known as role modelling. Indeed, research with so-called "successful people" in STEM indicated that while mastery experience was the primary source of men's PSE beliefs, social persuasion and vicarious modelling were more important for the women in the study (Zeldin, Britner, & Pajares, 2008). This gender difference highlights that a range of experiences may be necessary to generate a sustainable organizational culture of PE in higher education, with the resulting influences on societal perceptions of STEM. In particular, girls need to see women performing STEM activities successfully in order to believe that STEM is for them, while female STEM researchers need to see their fellow women academics succeeding in both their research careers and with PE activities.

Role modelling in engineering

Engineering is an interesting field in which to study PE organizational culture change, as it is the subject of several marketing campaigns to improve recruitment and retention to this career path (EngineeringUK, 2015; Perkins, 2013). Alongside this, efforts are also underway to improve the diversity of entrants and graduates in engineering; in the UK only 7% of engineers are female, while only 6% are from black and minority ethnic backgrounds (EngineeringUK, 2015). For women already in STEM careers, informal professional networks often provide the social persuasion and vicarious modelling needed to retain women in male-dominated fields such as engineering (Marra & Bogue, 2006; Shull & Weiner, 2002; Sonnert, Fox, & Adkins, 2007; Xu & Martin, 2011). Indeed, an unsupportive workplace culture was cited as the key reason why women leave engineering in one study of 2042 graduate female engineers (Singh et al., 2013).

Many engineering PE activities with school children also now focus on increasing recruitment of girls (EngineeringUK, 2015). Meeting scientists and engineers in person can be a powerful way to change children's (particularly girls') views of scientists and engineers, which they may receive through the media or their families, and as such boost their associated science capital (Archer, Dawson, DeWitt, Seakins, & Wong, 2015; Laursen, Liston, Thiry, & Graf, 2007). This is because attitudes at primary and early secondary school can influence later interest in STEM, particularly as children develop their gender identity and consequently their judgments about the appropriateness of STEM as a career before age 14 (Archer et al., 2013).

Furthermore, viewing same-sex in-group experts (female role models) has been shown to enhance subjective identification for girls with STEM, which in turn "inoculates" them against negative stereotypes and predicts enhanced PSE and commitment to pursue STEM careers (Stout, Dasgupta, Hunsinger, & McManus, 2011). However, simply seeing women in science and engineering fields is not always sufficient, as the experiences have to be positive for girls (Buck et al., 2008). Indeed, in order for women in STEM to be viewed as role models by girls, they need to walk a fine line between appearing to be competent in their field but not too dominating (Hoyt & Simon, 2011) but also not too 'feminine' (Betz & Sekaquaptewa, 2012). Conversely, women who fulfil the "geeky" stereotype of STEM professionals provide negative vicarious modelling and can actually put girls off STEM subjects (Cheryan, Siy, Vichayapai, Drury, & Kim, 2011; Drury, Siy, & Cheryan, 2011). It is important to highlight that this is not because girls are "fussy" but because they are also trying to ascertain their place in society, in order to fit into the social norms they receive by implicit messaging (Archer et al., 2012a, 2012b; DeWitt et al., 2011).

Culture change in engineering

Drawing on this research literature, the authors designed a science communication project which aimed to influence the organizational culture surrounding PE activities in a multi-disciplinary higher education engineering laboratory. Through training and support in storytelling at live public science events, it was hoped that a mixed cohort of engineers would improve their communication skills and sense of self-efficacy for PE, resulting in a vibrant, sustainable culture of PE activities beyond the life of this project. As part of this process, female engineers were purposively selected to take part in order to provide vicarious modelling for each other and for girls in the audiences. Thus the project had two overlapping aims:

1. To enhance the organizational culture of PE within the engineering laboratory, and
2. To enable female engineers to act as role models for the wider public, particularly girls.

Methodology

Project design

“Robots vs Animals” was designed to fulfil this brief as a year-long creative collaboration between engineers at the Bristol Robotics Laboratory (BRL) (Bristol Robotics Laboratory, 2016) and educators at Bristol Zoo Gardens (“Bristol Zoo Gardens,” 2016), both in Bristol, UK, during 2014-2015. The BRL was chosen as it houses over 150 staff in one multi-disciplinary laboratory (a collaboration of two local universities), and yet relatively little PE was undertaken at the time of project inception. Robotics is also a topic with much potential for PE (Laura Grant Associates, 2010) and that enables engineering to be presented as a creative problem-solving communal endeavor, as recommended to enhance the perception of girls (Adams et al., 2011; Diekman, Brown, Johnston, & Clark, 2010). The collaboration with Bristol Zoo Gardens was conceptualized as a way to reach audiences who were not perceived as traditionally interested in engineering (Institute of Mechanical Engineers, 2014). The project specifically targeted children aged 11-14 years (particularly girls) and public audiences at non-engineering events.

The project communicated the stories of the engineering design process undertaken by the engineers to create biologically inspired robots. The title was chosen to indicate the playful nature of the collaboration, engendering a spirit of conflict between biomimetic robots and the survival of the fittest animals. In reality, the project interweaved the design process inherent in creating biomimetic robots with the inspiring natural abilities of animals. Interactive sessions were set up at the zoo and the local science centre “At Bristol,” along with public events and festivals, and featured engineers and zoo

educators explaining and demonstrating the skills and processes of their respective charges within one storytelling process.

Training in storytelling was provided for early career engineers (ECEs) at the project inception. Storytelling is a social and cultural technique designed to present a narrative of events in an arousing way, which aims to capture the audience's attention (Haven, 2007). This technique was chosen, as research suggests it can make STEM subjects more approachable, engaging and memorable (Dahlstrom, 2014). Previous studies have indicated that storytelling techniques are effective to communicate computer programming (another male-dominated industry) to girls (Kelleher & Pausch, 2006) and to change teachers' perceptions of scientists (Kim, 2009). Storytelling skills are also useful for many PE activities, including face-to-face, digital writing, and social media formats (Durant et al., 2016; Robin, 2008), and so it was hoped the training would benefit the engineers in their careers. Training focussed on supporting the engineers to present their story in one line, a single minute, and a full presentation. The engineers were then supported by the coordinator in order to create a collaborative presentation with the zoologists. Four central themes (narratives) were developed throughout the project and featured swarm robotics, communication, sensing, and microbial fuel cells.

Drawing on the research literature describing factors which support PE organizational culture, five research supervisors, including BRL management team members, were recruited to help provide a network of support and leadership for other engineers in the laboratory. The research supervisors varied in their own experience of public engagement; however they all agreed to provide time allowances and advice to the ECEs recruited into the project. In order to remove barriers to participation, funding from the Royal Academy of Engineers was obtained to fund the research supervisors' time and to provide travel and kit allowances for the ECEs. A science communication coordinator was also employed for the duration of the project, providing a central connecting point to recruit the ECEs, support the development of the narratives, liaise with all collaborating partners, and organize the live public science events.

Drawing on PSE and social cognitive theory literature, the ECEs were all recruited into the project at the same time, in order to provide a peer support network. This was aimed at providing social modelling, social persuasion, and vicarious experience opportunities in order to boost PSE (Bandura, 2004). Targeted communications were directed at female ECEs in particular, in order to purposively create gender balance in the presenters. All live public science event sessions featured two engineers presenting together; this has been shown to be effective in facilitating paired peer knowledge exchange in order to enable mastery of communication and storytelling techniques (Fogg-Rogers, Edmonds, & Lewis, 2016). ECEs were also invited to watch the experienced research supervisors

undertaking PE at live public science events in order to provide further opportunities for vicarious experience (Bandura, 2004).

Evaluation methods

A quasi-experimental design was employed to evaluate the impacts of the project, with pre and post mixed methods data triangulated from two participant groups (ECEs and research supervisors). All participation was voluntary, with Ethics Approval given by the University of the West of England Faculty Research Ethics Committee. Audience responses to the events were evaluated using anonymous paper questionnaires and metrics of attendance; data about positive audience reactions has been reported elsewhere (Fogg-Rogers, Sardo, & Boushel, 2015); this paper focuses on the culture of PE for the engineers.

The ECEs completed a questionnaire before participating in the project, which collected demographic data and assessed their prior experience of PE and motivations for involvement. PSE was measured before and after their participation in the project using the Education Outreach Self-Efficacy Scale (EOSS) (Fogg-Rogers et al., 2016). Educational outreach was considered the best proxy for PE activity, as no scales were available for general PE; also, as PSE is domain specific (Bandura, 2006), it was considered appropriate to measure PSE for activities relating to communicating research concepts to young people (Fogg-Rogers, Wilkinson, & Weitkamp, 2015), which is what the ECEs were doing in this project. The scale measures 12 concepts related to educational outreach (Fogg-Rogers et al., 2016), with the score for each question being averaged to provide the overall scale mean for PSE, as recommended by Bandura (Bandura, 2006). Quantitative questions were analyzed using descriptive statistics in Microsoft Excel. Pre- and post-EOSS results were compared over time (before and after) within group using a Wilcoxon Signed Rank statistical test and between male and female groups using a Mann-Whitney U-Test in SPSS v10.

Semi-structured interviews were conducted at the end of the project with the research supervisors and ECEs, asking questions about their previous PE activity, their reactions to this project, and their thoughts on supporting future PE organizational culture. The interviews were conducted by a researcher (MS) who had not been involved in the project delivery to enable open conversations. The interviews were audio recorded and then transcribed verbatim by professional transcribers.

The transcripts were cleaned for conversational utterances and read several times for familiarity. The data was then analysed using the process of Thematic Analysis (Braun & Clarke, 2006) in QSR nVivo 10 software, with the unit of analysis being themes that captured patterned meaning across the data. Initial codes were inductively generated and then reviewed using a process of intra-coder constant comparison (checking for consistent meaning by one person). The codes were then refined and

accumulated into themes that represented the semantic meaning across the dataset. This review process enabled the themes from both the ECEs and research supervisors to be triangulated into one thematic hierarchy. Secondary analysis was performed by review by the co-authors to ensure the themes adequately represented the original data. Further discussion ensured the names of the themes also represented the meanings that were implied by the data. The three top-level themes identified were Project Design and Process, Communications Skills and Confidence, and Public Engagement Culture, with the sub-themes (outlined in Table 1) illustrated below in the Results section.

Table 1: The thematic hierarchy arising from the qualitative interviews with the engineers

Top-level Theme	Sub-Theme
Project Design and Process	Collaborative ecosystem
	Communication
	Coordinator and training
	Events participated in
	Future project improvements
	Motivations for participating in Robots vs Animals
	Previous experience
Communication Skills and Confidence	Communication
	Role models
	Storytelling
Public Engagement Culture	Public engagement benefits
	Public engagement drawbacks
	Supporting engagement

Results

As this was a mixed-methods project, the quantitative and qualitative data have been triangulated to enhance the analysis. The findings will be interwoven in this section according to the themes identified in the thematic hierarchy.

Participant and project characteristics

Ten ECEs were recruited to take part in the project, with five of these being women (50%). As engineering is a male-dominated profession, the proportion of women is much lower than men (20% female in the BRL), and so in order to present a 50/50 gender balance, the project organizers had to purposively recruit women to the project.

In addition, the project enabled a further 14 engineers (5 female, or 36%) to participate in STEM Ambassador training (STEM Ambassadors, 2016) as part of their PhD program, resulting in presentations from 29 engineers throughout the project. Eight of these additional engineers participated in public events under the Robots vs Animals theme but did not form part of the evaluation as they joined the project mid-way through.

The participating ECEs varied in their career stage and prior experience of PE. Five of the ECEs were PhD students (50%), two were post-doctoral fellows (20%), two were research associates (20%); and one was a lecturer (10%). Two were from minority ethnic backgrounds (one man and one woman). Nine out of the ten were aged between 25-40 years old and one was aged 41-60 years old.

Questionnaire data and the qualitative theme of “previous experience” indicated that most of the ECEs had very little previous experience with PE or outreach apart from teaching in schools or universities; only the older ECE (Engineer 10) described extensive prior experience.

Five male research supervisors (two from the BRL management structure) voluntarily participated in the project. No research supervisors were female (a significant under-representation) because the female group leaders do not work in biomimetics, which was the topic of this project. The research supervisors were all aged 41-60 years old, were white British, and had prior experience of PE and media work; these characteristics are reflected in the literature (Bauer & Jensen, 2011; TNS, 2015).

In total 24 events were organised with Bristol Zoo Gardens and at local schools, reaching 1110 children aged 11-14 years. Further public sessions were organised at local festivals and events across the south-west UK, reaching 180 adults in interactive presentations, along with thousands of passing contacts through festival exhibits. The narratives have been developed further through a schools competition, website (“Robots vs Animals,” 2016), social media (@robotsvsanimals), written materials, online videos, activity guidelines for public events, and teaching materials for schools. The

schools' competition received 70 entrants, the website received 3300 visitors during the project, and the teaching materials have been downloaded over 700 times; positive audience reactions to these events and materials are described elsewhere (Fogg-Rogers, Sardo, & Boushel, 2015).

Project design and process

The reasons the ECEs gave for participating in the project were in line with previous literature (Dudo & Besley, 2016; Martin-Sempere et al., 2008): they wished to educate the public about their work and inspire interest in and enthusiasm for STEM. In the pre-questionnaire, a question rating motivations to participate indicated that the majority of ECEs were participating in the project to “gain experience of public engagement,” “improve their communication skills” and “raise awareness of their research area”. This was reinforced by qualitative interviews at the end of the project, with the theme of “motivations to participate in Robots vs Animals” represented by these quotes:

I think that as an engineer, I feel like if I don't make an impact on society, there is no point in doing engineering, because at the end of the day, what you're creating in your life will have a consequence and the outcome I think needs to be told to the public right at the beginning. (Engineer 6, ECE, Male)

I'm quite enthusiastic about outreach because you should be able to communicate your own research, and it's also good to give something back to inspire a younger generation into areas of science and technology. (Engineer 10, ECE, Male)

Qualitative data in the sub-theme “event participation” indicated that all participants viewed the project positively and reported that it was a worthwhile endeavour. The ECEs animatedly recounted their experiences and also positively discussed the benefits of taking part in the project with a large cohort of peers and external organizations. This wider impact of the project on the PE ecosystem of the laboratory was discussed in the sub-theme of “collaborative ecosystem.” The research supervisors in particular noted the benefits of peer mentoring and external collaboration, and indicated that this would be a legacy from the project, as represented by these quotes:

[The organizers who] were running the project very carefully put the right people together; that someone who had a bit more experience with someone that hadn't had much experience interacting with other people and with children especially. They learned a great deal from it and enjoyed it a great deal. (Engineer 11, Research Supervisor, Male)

[It's] been very positive for those individuals [ECEs] and of course for the lab. It means that the lab is therefore, in a sense, growing a group of skilled and experienced public engagers. (Engineer 12, Research Supervisor, Male)

The sub-theme of “future project improvements” highlighted that there were some difficulties with event organization, marketing, travel liaison and robot malfunctioning; these are highlighted in the project report for other science communicators to learn from (Fogg-Rogers, Sardo, & Boushel, 2015). However, all of these problems were tackled by the coordinator as the project proceeded.

Indeed, the sub-theme of “coordinator and training” was the most cited topic, with all 15 of the engineers indicating that a key element of the project’s success was having a coordinator available to organize the project events and communications. Both the ECEs and the research supervisors identified that the role of a science communication coordinator required very different skills from their own. While many did cite the personality of the coordinator herself as being a success factor, most did also identify the relationship-building role of the coordinator needed to organize the highly collaborative project featuring both live events and digital engagement. The ECEs also praised the communication training and support available from a coordinator, as evidenced by these quotes:

I mean the support was excellent, far beyond anything I've seen before in my experience. I think it will do [the project will have an impact on public engagement] because of the structured approach, I think because of the support, the enthusiasm, mainly through [the coordinator]. (Engineer 10, ECE, Male)

I think it [a coordinator] was a very important figure in the project. Because without someone to do this public relationship, as researchers we don't have the contacts, the know-how to contact the venues and so I think it's very important for the lab to have someone given the task of public engagement and then read through to the scientists. (Engineer 7, ECE, Female)

Research supervisors also indicated that the coordinator role enabled them to support the project by removing time and organisational barriers to PE, as evidenced by this quote:

What was attractive was that some of the work had already been done and there were personnel in place that would take over some of the things like the fundraising and coordinating, so it wouldn't be completely something that we would have to manage by ourselves. (Researcher 14, Research Supervisor, Male)

This sub-theme provides a compelling argument for the provision and development of science communication professionals to support PE activities in higher education and supports the proliferation of science communication training courses (Mellor, 2013; Mulder, Longnecker, & Davis, 2008).

Communication skills and self-efficacy

A central aim of the project was to improve the communication skills of the ECEs, boosting their confidence and PSE to undertake more PE activities in the future. To this end, the project was structured with storytelling training, coordinator support, and a peer/mentor support network. The ECEs all discussed how the project had given them experience in new skills and situations and as such had improved their confidence for the future. The following quotes represent the “communication skills” sub-theme:

I think it's a very good project. It's a good learning curve for me; I get to talk to people about my work instead of just keeping it to myself for now. It's good for my personal development and also for my career development as well. (Engineer 3, ECE, Female)

It gave me intrinsic knowledge of looking at my research and trying to show everything from that point of view. I had to put myself in their shoes to be able to understand my work, so that has given me another insight in terms of when I look at something which is very complicated, there's always a way to make it simple, there's always a way to express it in a very simple word so that everybody can understand it. (Engineer 6, ECE, Male)

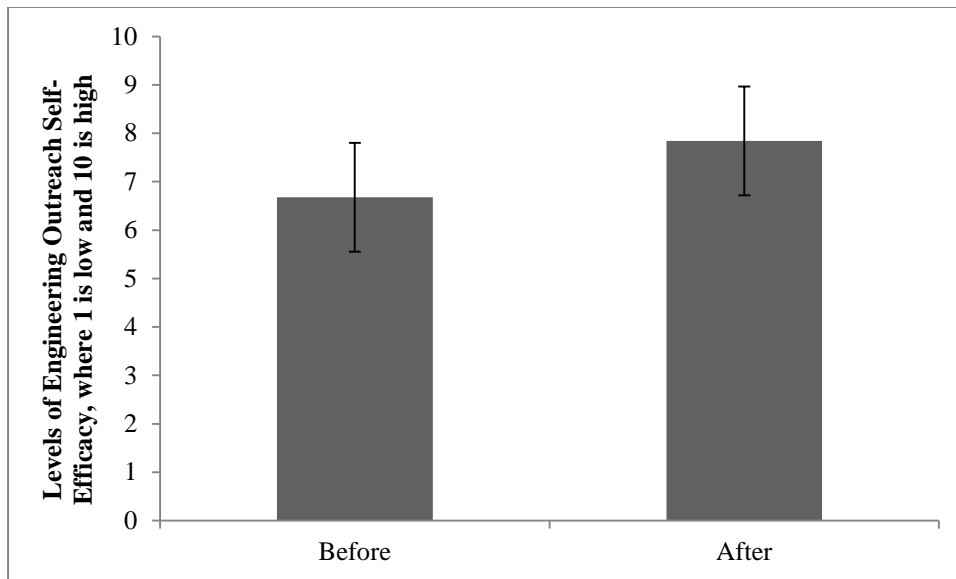
The communication skills training was based around storytelling techniques, and the project focussed on generating collaborative narratives to present at live public science events. While two of the more experienced ECEs didn't find this added to their skillset, the eight less experienced engineers gave these techniques positive reviews, providing further evidence for the usefulness of storytelling to improve communication skills (Dahlstrom, 2014; Kim, 2009). This sub-theme is reflected in these quotes:

We had to present it in a way that it's easily accessible. So there had to be a narrative story; why is it done and what we're inspired by and things like that. It's quite difficult for engineers to communicate about their work but throughout the activities like that we learn how to do it. (Engineer 2, ECE, Female)

[Stories are] more engaging. And before, I think it was already engaging because of the topic, but maybe people like to look more scared about the robotics and the things that they don't know and if you tell as a story, it becomes more reachable for them to understand the concept. (Engineer 7, ECE, Female)

This qualitative data is reinforced by quantitative data from the Engineering Outreach Self-Efficacy Scale (EOSS). Following participation in the project, levels of EOSS for the ECEs significantly increased from a mean of 6.68 out of 10 (*SD* 1.12) to a mean of 7.84 out of 10 (*SD* 1.21) ($Z = -2.60, p < 0.01$), indicating that the ECE cohort had significantly improved their PSE for educational outreach (one form of PE activity). These results are visually represented in Figure 1. Statistical analyses were also carried out to examine differences between how the male ECEs and female ECEs answered the scale, but no significant differences were found either before the project or afterwards, indicating that while levels varied within the cohort, these differences were not significant. Furthermore, no matter what level the ECEs started on, they all either stayed about the same or improved their personal EOSS score. The ECEs indicated in the interviews that they would continue taking part in PE activities beyond the life of the project; this is consistent with literature indicating that people with high PSE continue to perform that action (Bandura & Locke, 2003; Chen & Usher, 2013).

Figure 1: Levels of Engineering Outreach Self-Efficacy Before and After Participation in Robots vs Animals



Engineering role models

This sub-theme was a central topic for our paper and as such is discussed in detail here. All of the engineers (male and female) indicated that they wished to influence perceptions of engineering and engineers by personally taking part in face-to-face PE at live science events. Many engineers indicated that they viewed audiences engaging with the people doing the research as being just as important as discussing the science and engineering design process itself, as evidenced here:

The impact has really been on the kids and the audience - to be able to inspire them and reach them with a knowledge that we have. Because for some people, engineering is all about maths, but engineering is really the science of the practical. So I enjoyed discussing and I enjoyed demystifying engineering. (Engineer 6, ECE, Male)

I'm assuming actually that some of the engineers broke the mold of how a child might envisage a robot scientist to be. I mean you probably think of them as quite geeky, but some of our robot scientists are quite extrovert and they were normal looking people. So even though it wasn't stated as such, they probably picked up the message that actually robot scientists are just cool people really. (Researcher 14, Research Supervisor, Male)

However, there was a large variation in opinion about whether purposively selecting for a range of demographic characteristics amongst the engineers undertaking PE activities was or should be relevant to promoting engineering or PE. In particular, this issue was discussed with regards to recruiting girls and women into engineering. Female participants tended to agree with purposive

recruitment in order to represent a gender-balanced view of engineering to the next generation of potential engineers (both boys and girls), as indicated by this quote:

I think it is good to have a woman presenting in sciences to show them things instead of ...[men saying] to a girl “Oh yeah, you can do this.” That is not necessary. I think [an] equal distribution of outreach activities between women and men would be really nice to show that both [genders] can be engineering staff. So if for example an outreach activity involves ten people, the ideal would be five women and five men, not nine men and one woman. (Engineer 4, ECE, Female)

This is consistent with the argument that girls need to see women in STEM careers in order to provide role models, or vicarious experience (Archer et al., 2015; Buck et al., 2008; DeWitt et al., 2011). However, some female participants discussed the delicate balance they would need to strike between remaining professionally competent and not simply being selected for their gender (Hoyt & Simon, 2011), as indicated here:

What I do is work that I’m proud of. So it doesn’t matter if I’m a man or a woman to inspire someone, but [the] best idea would be to have both the sex[es]in [assumed to mean equal representation]. (Engineer 2, ECE, Female)

However, a policy or aim of gender-balancing was not universally supported by male participants. Some male engineers did support efforts to recruit more women into engineering, and they also agreed that equal representation in public events was important, as exemplified by these quotes:

You know the lack of women in engineering and STEM in general is shocking, it’s disgraceful. I’ve [heard] it described as wasting essentially 50% of the human potential on the planet and that is absolutely true. I think one of the ways that we address that... is by having great role models and so I think it’s extremely important. (Engineer 12, Research Supervisor, Male)

It’s very important for people to have role models that they [children] can identify with, I think, so it is important to have that broader demographic of people that are trying to put across the things to try and deal with the stereotypes that are endemic in engineering. (Engineer 9, ECE, Male)

However, other male engineers disagreed with the idea of “positive discrimination,” as they felt that everybody should be treated equally based on their own skills and abilities. Practical difficulties were also raised by one engineer, who discussed in detail his attempts to recruit women to PE activities but the sheer low numbers of undergraduate female engineering students made this difficult; indeed, the

same women were being asked to participate on multiple occasions. This was echoed in a previous small-scale study undertaken by the corresponding author, where female scientists expressed their dislike at feeling an obligation to undertake PE activities “just because they are women” (Fogg-Rogers, Wilkinson, & Weitkamp, 2015). Some of the male participants also indicated resentment that by emphasizing the role of women in engineering, both male engineers and boys in school would then be missing out, as evidenced here:

Employing women just for the sake of employing women and making their numbers up - I think it actually undermines and devalues the participation of women in such events. The quality is in the scientist regardless of gender. (Engineer 15, Research Supervisor, Male)

Maybe constantly throwing girls at them in engineering isn't actually working and maybe there's another way to do it... I do feel sometimes there could be more encouragement, positive encouragement, for boys to be doing it as well where I think boys can miss out because it's just assumed that that's what they're going to do. (Engineer 8, ECE, Male)

Public engagement culture

The sub-themes of ‘public engagement benefits’ and ‘public engagement drawbacks’ highlighted many of the concepts already identified in this paper’s introduction, indicating that the issues identified worldwide in PE were also valid in this engineering laboratory. In the sub-theme of “supporting public engagement,” the engineers described how organizational decisions could encourage and enable more PE activity, thereby creating a culture of PE. Collaboration with external organizations, endorsement from senior management colleagues and support from a coordinator were identified as being integral to the continuation of the project, so that engineers felt PE was required and supported by their employers. However, some participants did question whether these enablers would continue beyond the life of the project, as exemplified here:

I mean, from a university perspective, it there's some kind of credit towards you doing it, there's some kind of benefit that's going to help you, kind of incentivize you, that could enable you to keep the momentum of doing it. (Engineer 8, ECE, Male)

I mean people do their best, the trouble is we're all working hard and without some specific funded project like this, it's hard to justify spending the time on it [public engagement] because there are always more immediate and more urgent things to be doing. (Engineer 11, Research Supervisor, Male)

Despite this, two research supervisors who were influential in the BRL management team indicated

that the project had made a significant change to the value and appreciation for PE in the lab. This indicates that the normative culture in the laboratory had changed and that PE activities were more recognized and supported, which indicates that junior ECEs should feel more able to continue these activities beyond the project (Dudo, 2013; Poliakoff & Webb, 2007). These quotes exemplify this culture change:

I think it's raised the profile of public engagement, which I have to say has up until now, or at least up until Robots vs Animals, public engagement was never really particularly well regarded in the lab, particularly I have to say among some of the senior people in the lab. (Engineer 12, Research Supervisor, Male)

It already has had an impact on the nature of... [public engagement], in fact we're already planning to embed these kind of projects in other research bids because it's gone so well. (Engineer 11, Research Supervisor, Male)

Perhaps in recognition of this, the coordinator was employed by the BRL for another year following the project in order to generate more PE activities and support, and STEM Ambassador training has also now been incorporated into future PhD programs.

Conclusion

This science communication project drew on behavior and culture change approaches supported by social cognitive theory, indicating that these methods can be successfully applied to PE activities and high education environments. During the year-long project, there was a widespread increase in PE activities taking place in the engineering research laboratory. While some individuals had previously undertaken PE activities, there was not an expectation that all engineers would take part in PE. Through the sustained efforts of the project, this research culture is now changing.

Critical to this culture change was the support of senior management and research supervisors. Workplace culture is usually set by leaders, and junior staff members replicate behaviours which are rewarded or recognised by others in their community (Dudo, 2013; Marcinkowski et al., 2014). Secondary to senior management mentoring support was a peer support network, with a cohort of engineers having the same experiences, enabling them to seek advice and help from each other (Singh et al., 2013; Xu & Martin, 2011). These mentor and peer support networks are crucial to enable social learning within organisational cultures (Bandura, 2001, 2004; Bandura et al., 2008).

Indeed, participation in the project significantly increased perceived self-efficacy for educational outreach, a proxy measure of PE, for both male and female engineers. We believe this was facilitated through using approaches identified in social cognitive theory. Firstly, direct learning experiences were provided through training in storytelling to improve communication skills, and then experiencing success at live public science events, thus providing positive emotional arousal to enable a feeling of mastery when remembering previous performances (Anderson & Betz, 2001). Secondly, indirect learning experiences were also provided through social persuasion and approval from peer group engineers taking part, and vicarious modelling through watching others perform (Bandura, 2004). This approach thus mixed opportunities for vicarious experiences (identified as being important for women) and mastery experiences (identified as being important for men) (Marra & Bogue, 2006; Zeldin et al., 2008). This may be why both men and women significantly improved their PSE and why we found no significant differences between the increase in PSE for men or women.

Qualitative interview data reinforced this quantitative finding, providing evidence for social cognitive theory approaches; namely providing communication training and opportunities to practice in order to experience success, alongside developing a collaborative peer/mentoring culture. Furthermore, provision of funding for researcher workload time and administrative support from a science communication coordinator were important to remove barriers to participation in the project. This is in line with literature about reasons why scientists don't participate in PE activities, citing conflicting workload demands and little incentive to prioritize PE organisation (Besley et al., 2013; TNS, 2015). All fifteen engineers praised the complementary skillset of the coordinator, enabling on-going support and training, and the development of collaborative relationships with other regional organisations to facilitate live public events and digital engagement. This reinforces calls for greater functional support for PE in higher education (Duncan, Manners, & Wilson, 2015; France et al., 2015), which may subsequently help to generate greater research impact evidence from PE activities (Fogg-Rogers, Sardo, & Grand, 2015).

Both male and female engineers were keen to participate in PE in order to inspire interest in and enthusiasm for STEM. The engineers discussed how they wanted to change perceptions of engineers and inspire children to continue with STEM subjects and careers, which is in concurrence with the literature (Jeffers, Safferman, & Safferman, 2004). However, the issue of purposive recruitment of female engineers in order to generate a gender balance amongst the presenters proved controversial for some male engineers. Drawing on previous literature (Archer et al., 2013; Bandura, 2001; Stout et al., 2011), we argue that purposive recruitment in male-dominated fields is incredibly important to normalize female role models in STEM and also to broaden implicit societal messaging about which careers are appropriate for girls. However, we recognize that there is a conflict that must be managed to ensure these activities do not become overly burdensome for female engineers and more

importantly they should be properly rewarded through funding or promotion procedures. Previous studies have indicated that undertaking PE can be perceived as a “soft option” that reduces career trajectories (Besley et al., 2013); it is important that this does not become linked to gender and introduce a stereotype threat (Shapiro & Neuberg, 2007). Furthermore, in response to criticism that boys or men will be disadvantaged by ‘positive discrimination’ against them, we would highlight research that indicates that boys are not ‘put off’ by seeing female role models in male-dominated sectors (Carrington & McPhee, 2008; Lockwood, 2006).

Implications for practice

Approaches from social cognitive theory have been applied in this science communication project, with the aim of changing the culture of PE in higher education. However, this was a small-scale study in one engineering laboratory. To fully generalize these conclusions, we would recommend repeating this project on a wider scale, perhaps involving several higher education institutions working together. This would provide a larger sample and more statistical power in which to fully assess changes to PSE for educational outreach and PE. However, the proposed mechanisms for change can still be put into practice now: support from science communication coordinators, mastery of storytelling communication techniques at live science events, social persuasion to alter the normative culture, and vicarious modelling to witness others performing PE activities.

Future social science research may need to look at the understanding and acceptability of actions that aim to tackle gender (or other) inequality amongst engineers and scientists to ensure that such practice is accepted and enacted within the STEM community. Raising the profile of women in STEM is a widespread high-level aim within recruitment and PE in the sector, but if many (perhaps particularly men) within the field see this as harmful or ‘unfair’ then the roll-out of such actions will be hampered. Furthermore, the delicate balance between being adept at one’s career and portraying an image that is not too “feminine” or too “dominant” needs more research. The extra burden this focus on role models places on underrepresented groups to not only be a minority within their field but also to be role models and represent their demographic and their field must be managed. To this end, consideration should be given for mechanisms to reward and recognize PE involvement in academic career paths in higher education institutions in order to enact widespread culture change. By supporting a wide diversity of scientists and engineers to regularly engage in PE activities, it is hoped that the societal impacts from science communication will be felt more broadly.

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The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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