Changing the Digital Landscape: A Participatory Action Research Project to Increase the Representation of Women using Digital Science Communication

By

Kristy Burke

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Abstract

This purpose of this paper is to outline the issue of fewer women than men engaging in digital science communication (DSC) and how a participatory action research (PAR) approach was blended with a developmental research framework to facilitate a team of volunteer researchers. I discuss the general trends observed in the literature regarding science communication in both offline and online contexts, as well as the overriding issues contributing to women's current underrepresentation in science, technology, engineering, and math (STEM) and in DSC. Throughout my description of the PAR process I discuss some of the key ideological and ethical considerations I encountered during the process and how the academic evaluation of PAR should include criteria specific to the ideals of the paradigm. As a result of this project, research team members completed the initial design of interventions developed to increase women's DSC engagement, culminating from their findings that motivation, scientific knowledge, communication skills, and digital literacy were key influencers in determining the level at which women in their target audience chose to engage in DSC. Outcomes of this project demonstrate how PAR helps individuals and organizations collectively generate knowledge that has the potential to catalyse social change, serving as a tangible link between theory and practice in professional, organizational, and social settings.

Keywords: participatory action research, women in STEM, digital science communication, developmental research, digital literacy

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Chapter 1: Introduction

A case for engaging more women in digital science communication

Digital media is becoming an increasingly popular way to communicate complex scientific and technical information to the public, yet fewer women than men use it for science communication. This suggests the underrepresentation of women in science, technology, engineering, and math (STEM) is mirrored on the web. With the latest generation of women scientists emerging from a predominantly digital culture, the low number of women engaging in digital science communication (DSC) raises some important questions. Are the traditional gender barriers women face in the offline world at fault? Or has the digital gender divide added a new level of complexity to an already existing problem?

The current literature shows several benefits of engaging in DSC. Digital media provides a potentially far-reaching avenue of communication between scientists and the public, helping to increase science literacy, and it creates numerous professional benefits for the individuals who use it to share their scientific work. It's a means to combat pseudoscience (Riesch and Mendel, 2014), to build bridges of trust between the scientists and non-scientist communities (McClain, 2017), and to support science-based decisions on numerous local, provincial, and national levels (Neilson, 2015; Wilcox, 2012).

There are diverse platforms and applications available to create and share digital science content and women's voices should not go unheard in the numerous important STEM conversation taking place online. Creating digital media content can empower women by allowing them to voice their concerns over science-related issues, develop their science identity,

and participate in educating the broader public (Dahya, 2017). Mindful digital media practices can also help young women increase their self-esteem (Yang, Holden, Carter, 2017).

Having parity between men and women communicating about science online can help normalize the presence of women in offline STEM communities. Studies have shown that time and time again, young women lose interest in STEM as they progress through their education and career, making women a visible minority in these fields (Glass, Sassler, Levitte & Michelmore, 2013; Kinzie, 2007). With more and more young people accessing their information online, it's important for them to see women talking about science via social and digital media because it helps to remove the stereotype that science is better suited for men, strengthens the female science community, and increases young women's confidence in reaching their own STEM potential.

As someone with several years of experience in designing programs to help young women hurdle some of the social barriers encountered in STEM field, the issue of so few women engaging in DSC prompts me to ask, "*What kind of programs or educational opportunities will encourage more women to use digital media to communicate science?"* However, the answers to the latter question hold little stock if there is no one to implement these programs or educational opportunities, a factor that caused me to turn my focus to the University of Alberta's Women in Scholarship, Engineering, Science, and Technology (WISEST) program.

I believe outreach programs like WISEST have the potential to encourage more women to engage in DSC because they already have valuable resources and knowledge in place. For over 35 years, WISEST has helped thousands of grade school girls and university women within Alberta pursue STEM careers. Their mission is to engage young women in STEM through hands-on experience, active participation, mentorship, networking, outreach, and education

("WISEST mission," November 2017) and the programs, workshops, and learning opportunities they offer are designed to address the social barriers faced by women in STEM. Their reach is amplified through the work of their affiliate networks that operate under the WISEST umbrella: *UA-WiSE* (University of Alberta Women in Science and Engineering), an undergraduate student-led group, and *WISER* (Women in Science, Engineering, and Research), a graduate student/early career group (for this project, I refer to all networks collectively as WISEST). However, none of these groups currently offer programs to help women in STEM advance their *digital science communication* (DSC) skills.

Initiating change through participatory action research

Inspired by the above-mentioned need for action, this project adopted a *participatory action research* (PAR) approach to explore the issue of fewer women engaging in DSC. PAR begins when a group of people share a common concern and want to take action to address it (McTaggart, 1994). It is a collaborative form of inquiry where participants negotiate what it is they want to accomplish, the methods they employ to achieve their goals, and a shared understanding of the issue under investigation (Hawkins, 2015). Furthermore, PAR engages professionals and academics as co-researchers who are seeking to develop theory-driven practices to promote change for some kind of social improvement (McTaggart, 1994).

I selected a PAR approach because I wanted my work to lead to tangible action that encourages more women to step up and communicate about science online. I believe to do this, we should seek to empower outreach organizations, like WISEST, with the knowledge and tools they need to intervene with their respective audiences. These are the people who can be the instruments of change because they have the capacity to develop a deeper understanding of the issue and often have existing resources in place to help enable action. Outreach programs are by

nature action orientated, and this project was an opportunity for WISEST to gain a better understanding of an issue they had not yet explored and to empower themselves to develop programs and initiatives that engage more women in DSC.

PAR is often employed by educational researchers and the similarities between their work and mine prompted me to turn to developmental research, the study of designing, developing and evaluating instructional programs or materials (Richey & Klein, 2005) to investigate potential ways to guide my work. As a result, I applied an integrative learning design (ILD) framework (Bannan-Ritland, 2003) to the project, which served as a flexible guideline for the research process that unfolded.

Defining the research project

This purpose of this project was to address the issue of fewer women engaging in DSC through PAR. It was my intent to empower WISEST with the knowledge they need to help women increase their capacity in DSC and ultimately stimulate action to increase women's online presence in STEM. This paper presents the current literature around the broader issue of women being underrepresented in STEM, trends and complexities in science communication moving towards digital media, and the various phenomena influencing women's engagement in DSC. I discuss how the ILD framework was applied to PAR to help guide a volunteer WISEST research team through the process of forming a research question, defining their methods, and gathering and analyzing data to achieve a more critical understanding of why so few women engage in DSC. I also discuss the resulting initial design of interventions and educational strategies the research team developed in response to the key factors they identified when examining what impacts their audience's engagement in DSC.

I approached this capstone as a learning project, in which I played a facilitative role, and it's important to be clear that by participating in this project, the WISEST research team members were not subjects in a qualitative study, but rather they were researchers generating knowledge from a process they defined as the project unfolded. My intent in this paper is to describe the project as it developed and to outline the ways in which PAR ideologies were woven into the process. I also discuss some of the ethical and academic dilemmas I encountered during the process and how redefining the validity criteria for PAR is important when evaluating the academic rigor of PAR, which does not always fit into more traditional academic molds.

Chapter 2: Literature Review

Literature Review Methodology

This literature review outlines recent research on the current status of women in STEM, the complexities involved with moving science communication into the digital realm, and how women in STEM currently fit into the DSC landscape. Findings are outlined under the following major headings: *(a) Methodology, (b) Discussion of the Literature, (c) Conclusion.*

To begin my search, I used the University of Alberta's Library EBSCO database, recording the search terms and combinations I used to avoid duplication at later dates. I applied Boolean logic to search a combination of terms and phrases, such as *women in STEM, women in digital science communication, women in science and communication, women in STEM and ICT, scientist and social media, women and digital identity.*

Search Parameters

In reviewing the literature around my research topic, I set numerous parameters to conduct my search, as described below:

Year of publication. To understand the current landscape for women in STEM using DSC, I felt it important to use recent findings. Therefore, I tried to limit my search to ***research conducted within the last five years***, particularly when looking at work related to digital media. However, I extended the publication date range where I felt it necessary, such as for historical or theoretical context or when recent publications were limited.

Peer review. The second parameter I set was to identify research from scholarly peer-reviewed journals. This parameter was important to my search because most of the research I reviewed was conducted within the last one to three years, so most were not highly cited work.

Requiring peer review mitigated for the latter and ensured the research I reviewed met academic standards.

Cultural relevance. I felt it was also important to limit my search to research done within a culturally relevant, or similar, environment to that of the project. Preliminary searches revealed a significant amount of research around gender digital divides and women's use of digital media in developing countries, however, the cultural and social landscape of these studies is significantly different from the current context being considered – a Canadian university where women have access to modern technologies and popular digital communication platforms. Thus, I focused my search first on Canadian studies and then extended it to include culturally similar areas such as the US, Australia, and parts of Europe.

Grey literature. Lastly, I should note that my review is not exclusively limited to journal articles. It also includes a limited number of editorials, news articles, and resource books that contribute to the understanding of my research problem. Data from government and association reports were also reviewed to gather useful demographic and statistical information about the status of women in STEM in Canada.

Organizing and Categorizing the Data

To manage the articles gathered in my search I documented them in an Excel file where I recorded their effectiveness in meeting the above-described search parameters. I then categorized articled by themes (e.g. women and digital communication, scientist us of social media, and digital identity). Many articles supported more than one theme and after a more thorough reading, additional themes were also identified (e.g. community, self-efficacy, gender stereotypes).

Discussion of the Literature

Women in STEM: Understanding the current landscape. That there are fewer women than men in STEM fields is mostly undisputed in the literature. Data from Canada's 2011 National Household Survey (NHS) indicates that even though 59% of university students are female and comprise two-thirds of Canada's non-STEM graduates, they account for only 33% of STEM graduates (Dionne-Simard, Galarneau, LaRocelle-Cote, 2016). Regardless that these numbers are up from the 1991 NHS data, there are significant differences observed between the increase of women in specific STEM fields, the most notable being the little to no increase in women pursuing computing science and engineering. Furthermore, of the 304,000 university-level science-related jobs created in Canada between 1991 and 2011, only 27% of these were filled by women, whereas women comprised 75% of the non-science positions created during this same time period (Dionne-Simard et al., 2016).

The "*STEM pipeline*" is a common term used to describe the recruitment and retention of girls and women to STEM. Over the past thirty years, researchers have observed critical junctures, or points at which girls and women tend to leave the pipeline, occurring as early as middle school and persisting into university and early career years (Glass, Sassler, Levitte & Michelmore, 2013; Kinzie, 2007). For this review, I chose to focus on (a) high school to undergraduate years, and (b) early career aged women, where early career aged women are either graduate students or women who have recently finished a degree and entered the professional field. These groups represent the demographics served by WISEST and its networks and therefore, I feel it is important to understand the general challenges they face in pursuing STEM and I discuss each group below:

High school to undergraduate years. One strategy to better understand the “leaks” in the STEM pipeline is to look closely at the educational pathways of young women. Critical points in young women’s decisions to pursue STEM are usually observed in grades eight to nine, when they make the decision to move on to senior level math and science courses, the final year of high school, when they make decisions about post-secondary, and mid-university degree, when they often have to declare a specialization (Kinzie, 2007). Students’ career aspirations are linked to their cognitive abilities and interests, and self-perceived low science and math achievement in high school are the most frequent filters to students entering STEM in post-secondary (Kinzie, 2007, Wang, Ye, and Degol, 2017). The latter can lead to girls who are not top performers in STEM choosing to exit the STEM pipeline either before university or early on in their university experience. Other factors in young women’s decisions not to pursue STEM include lack of information on university programs, misconceptions about STEM, and self-doubt about their STEM abilities (Christie, O’Neil, Rutter, Young, and Medland, 2017). If young women are not getting enough support or information about STEM in high school, they may be missing out on potential motivators not linked to their academic performance. For example, even though Wang et al. (2017) found that students significantly stronger in math and science gravitated towards those fields, they also found that students more symmetrical in their strengths (e.g. strong across all subjects) were motivated by their psychological beliefs (e.g. self-efficacy, task value, altruism) towards STEM. However, it should be noted that within the context of girls and STEM career choices, Wang et al.'s (2017) study is a bit limited in that it did not consider how the above mentioned motivational and psychological beliefs differ between genders.

Unfortunately, when women reach university, they are still vulnerable to the "leaky pipeline." Part of the problem might be that being a minority, women feel marginalized or not

part of the community. When Thoman, Arizaga, Smith, and Soncuya (2014) examined how a competing sense of belonging between STEM and Humanities-Liberal Arts university courses affected STEM class interest they found women's interest in STEM was negatively impacted when they felt a greater sense of belonging in their Humanities-Liberal Arts courses, but not when the latter was reversed. Self-efficacy is another factor linked to women's decisions to pursue STEM (Falk et al., 2013; MacPhee, Farro, & Cannetto, 2013) and is a variable that can directly influence their *interest* in STEM (Falk et al., 2013). Social Cognition theorist Albert Bandura (2000) claims, *"Perceived efficacy plays a key role in human functioning because it affects behavior not only directly, but by its impact on other determinants such as goals and aspirations, outcome expectations, affective proclivities, and perception of impediments and opportunities in the social environment",* (p. 75). In other words, if people feel good at something they are more likely to want to be involved in it. Women have been noted to have lower self-efficacy than men upon entering STEM university programs (even with no academic differences) but to experience an increase in self-efficacy as they progress in their studies (MacPhee et al., 2013). The latter suggests that using strategies to increase women's self-efficacy in STEM may help to keep them in the pipeline.

Demonstrating the social benefits of STEM has also been put forward as a mechanism to increase young women's interest in STEM. Diekman, Steinberg, Brown, Belanger, and Clark (2010) argue that women tend to care more about communal goals, or tasks, that are deemed important to society and which are often more linked to non-STEM careers. Their survey of 333 women supported this argument by highlighting a negative relationship between communal-goal endorsement and interest in STEM. Though their study was somewhat limited in scope (e.g. only included introductory psychology students), their findings are reiterated in Wang et al.'s (2017)

argument that feelings of altruism contribute to the motivational and psychological beliefs that influence career choice.

Early career years. The delicate sense of belonging women often encounter in STEM is further compromised as women advance in their careers as minorities frequently excluded from male-dominated professional networks and are given lower salaries and ranks than their male colleagues (Xu & Martin, 2011). Furthermore, their work is often subjected to gender bias and evaluated lower than men's work (Handley, Brown, Moss-Rucusin, & Smith, 2015). These challenges all contribute to women exiting STEM in the early to mid stages of their career. Glass et al. (2013) conducted a longitudinal US study to compare the career exit rates of women in STEM and non-STEM fields. Their results showed that women in STEM fields were far more likely to leave these careers than women in non-STEM professions (e.g. finance, management, nursing, lawyers), with nearly 50% of the women in STEM leaving their careers within ten years. Interestingly, Glass et al. (2016), considered variables like marriage and starting a family in their comparison but there was no significant difference in how these affected each of their study groups. In fact, women in STEM fields actually have many perceived benefits such as higher salaries and greater work-life balance supports. Yet their findings suggest the challenges women face earlier on in the STEM journeys may persist further down the “pipeline”.

Trends in Science Communication: Towards Digital Science Communication

In today's digital landscape, we can now receive and disseminate information about science in ways that make it potentially more far reaching and accessible than traditional forms of science communication. This has implications not only those on the receiving end of these communications but also on the sending end. Current literature suggests that scientists and

STEM researchers are predominantly using DSC in two key ways: (a) for public engagement or (b) for peer-to-peer interaction. Before examining what is known about women and DSC, it is important to first understand the contexts in which DSC has influenced their professions. Therefore, I begin with a general overview of digital science communication for public engagement and peer-to-peer engagement as outlined below.

Digital science communication for public engagement. Science communication can take place in both formal and informal learning environments and helps Canadians stay informed of new and cutting-edge research while fostering a greater level of public buy-in for science-based policy and decisions (Neilson, 2015; Wilcox, 2012). However, that less than 50% of Canadians surveyed by the Council of Canadian Academics could explain simple scientific concepts like the basic components of the experimental process or the term "molecule" (Council of Canadian Academics, 2014) raises some red flags about the Canadian public's current level of science literacy. In response to the latter issue, many scientists and science advocates have begun to consider how digital media can help open new avenues of science communication for increased opportunities for public engagement to elevate the public's understanding of science and perceptions of scientists.

In a guest editorial of the *Biological Bulletin* from the University of Chicago Press, Wilcox (2012), calls for more scientists to engage in DSC to help dispel negative opinions about scientists. She argues that scientists need to start making more of an effort to get involved in the public discussions about science and that having an online presence is the best way to do this. Some see the latter as a means for scientists to combat the spread of "bad" science becoming prevalent on the web (Riesch and Mendel, 2014), while others, like Wilcox (2012), see it as a way to break the sometimes elitist and negative perception of scientists. Neilson (2015) also puts

forward the argument that engaging youth in DSC is a means to keep them interested in STEM and to avoid losing them to the "leaky pipeline". Yet despite the above benefits, there are still varying levels of buy-in from the scientific community.

DSC has the capability of fostering two-way dialogue between the public and scientists, but research has revealed this is not always the case. Davies and Hara (2017) argue that audience engagement cannot be taken for granted because there is frequently a reversion back to well established one directional, top-down hierarchies in science communication. This argument is supported by Suldovsky, McGreavy, & Lindenfeld, (2017), who while analyzing the science communication dynamics of a research group, found researchers use more dialogic (two-way) communication for stakeholder audiences they perceived as having a higher level of expertise and more diffusion (one-way) communication for those they perceive as having a lower level. This poses a significant barrier to public engagement and negates many of the dialogical benefits of social media and blogging platforms.

Aside from enabling engagement with the broader public, social media dialogue may also have the potential to influence non-science individuals within scientists' own social media networks. McClain (2017) coined the term "Nerd of Trust" in his argument that scientists should break free of their tendency to only engage with peers about science on their social media platforms to use their trusted status within their Facebook friends to promote science in a positive and accurate way. Upon surveying 203 scientists, McClain (2017) found early career scientists have more non-science friends in their networks while the more senior scientists tend to have more peers to peer connections. He postulates that "as scientists rise in their scientific careers, their connections with other scientists increase and deepen because of either exposure to new scientific networks or potential isolation within the *ivory tower*" (McClain, 2017, p. 3).

Though the latter corroborates Collins et al. (2016) and Ke et al.'s (2017) findings on scientists' preference of using DSC for peer to peer interaction it does not acknowledge other potential influencers, such as generational differences or technical ability.

Blogging is another digital realm in which scientists can reach out to public communities. In a case study, Riecsh and Mendel (2014), looked at how the "badscience" blog community uses blogging to engage with the public, politicians, and mainstream media. Their findings revealed some interesting dynamics within the science blogging community, such as a mix of academic and non-academic community members and a culture that supports "informal peer review" in place of the rigorous academic vetting found in more scholarly publications. Yet despite this rigorous vetting, and numbers that suggest scientists read blogs, many are reluctant to author them. For example, 92% of scientists surveyed said they read scientific blogs (and 89% believed blogs do a good job of explaining science to the public), but only 50% said they authored them (Collins, Shiffman, and Rock, 2016).

Peer-to-peer digital science communication. One of the most prevalent reasons engaging in DSC is not an easy move for all researchers is because it breaks from traditional forms of scholarly communication where research is shared among peers or published in academic journals (Grand, Holliman, Collins, and Adams, 2016; Hunter, 2015). The lack of such vetting in some digital tools, like personal scientific blogs or social media platforms, has stigmatized these media for many scientists, even though they are an effective way to transport knowledge to the public sphere (Grand et al., 2016). There are also professional considerations, such as in Nicholas et al.'s (2017) findings that early career researchers (under 35 years old) prefer journal publishing to disseminate their research because this is how they are evaluated, promoted, and given tenure.

However, there is a clear pattern among research findings that indicates scientists are using digital media to communicate with their peers, which is significant in the context of building professional communities and creating scholarly connections. Collins et al. (2016) surveyed 587 scientists identified as social media users and found that rather than to communicate with a public audience, scientists preferred to use DSC to interact with other scientists. When the study participants were asked why they believed their fellow scientists did not engage in social media the most common responses were lack of knowledge about social media, not knowing how to start using it, and time constraints (Collins et al., 2016). Similarly, Nicholas and Rowland's (2011) research on the use of social media in the research workflow found that uptake of digital media usually relies on personal initiative and that researchers who are time-poor are less likely to see the benefits of using social media to communicate their research.

Peer to peer DSC may also appeal to some researchers because it reinforces their research identities. Lave (1991) argues that people inhabit multiple social worlds and therefore have multiple identities, a phenomenon that Grand et al. (2016) claim extends to the research world and the multiple identities assumed by researchers (e.g. scientists, author, teacher, etc.). Using qualitative data from an interview study, Grand et al. (2016) classified researchers' digital engagement identities, or types, as *(a) the "highly-wired", (b) the "dabbler, and (c) the "unconvinced."* Rather than argue that one type was more preferable, Grand et al. (2016) argue for a "pluralistic culture that appreciates the value of differences in digital capabilities" (p. 15), leading to a 'muddled culture', where researchers can support one another in adapting to the ever-changing nature of digital media. As part of their study, they sought to connect the varying levels of digitally-engaged researchers in a *community of practice* where researchers could

nurture a "muddling-through" culture by sharing their expertise. This intervention is an interesting strategy that might contribute to building researchers' scholarly identity.

Besides their preference to communicate with other science professionals, many scientists also have a preference to engage with those in their field. A large-scale systemic study by Ke, Ahn, and Sugimoto (2017) revealed that there was a preference among the 45,000 identified science professionals they analyzed on Twitter, to follow and share tweets from people within their own stream of science. This implies there are some disciplinary walls within Twitter that might impede the dissemination of scholarly information (Ke et al., 2017) and indicates a preference for peer-to-peer DSC consistent with Collins et al.'s (2016) findings.

Women and Digital Science Communication

That women in STEM are underrepresented on the web is supported in the majority of available literature. For example, in Ke et al.'s (2017) large-scale Twitter study (referenced in the section above), only 38.6% of those they could identify a gender for were women. Economist Neil Hall inadvertently shed some light on the lack of women scientist on Twitter when he created what he coined the "Kardashian Index" (K-index), a way to compare scientists' Twitter followers with their citations (You, 2014). Hall originally designed this index to make the point that some popular science figures should get off Twitter and write more papers, but in the process revealed that of the fifty most followed science "stars" on Twitter, only four are women (You, 2014). In another study, Shema, Bar-Ilan, and Thelwall (2012) analyzed how researchers were blogging about scholarly information and found women comprised only one-third of the population they sampled. Women are also underrepresented in popular new media websites that focus on science content (e.g. New Scientist) and are often associated with more feminine

discourse like caring, empathy, and working with children, whereas men are more often associated with the discourse around intellect and conducting experiments (Mendick & Moreau, 2013).

Unfortunately, the gender bias that has plagued women in STEM in educational and professional environments can be observed in science communication. Knobloch-Westerwick, Carroll, Glynn, and Huge (2013) conducted a study titled "*The Matilda Effect of Science Communication*" in which they asked science graduate and PhD students to evaluate scientific abstracts which were assigned author names to suggest either male or female authors. Abstracts with male names were rated as having a higher scientific quality even though they had been manipulated to avoid this. Gender bias also impacts the potential benefits that women in STEM can reap from engaging in DSC, as observed in a study by Sotudeh and Koshian (2014), which compared the scientific productivity (e.g. the number of citations) of web-present male and female nano-scientists. Even though they found no significant differences between the two groups, they did find web-present men significantly outperformed their offline male peers while there was no notable difference between the female groups. This suggests that men in STEM engaging in DSC are experiencing more professional benefits than women.

Despite negative experiences that might arise from encountering bias, engaging in digital media production for science communication can offer girls and women numerous personal benefits. Dahya (2017) contends that digital media production can give youth the opportunity to voice concerns over social injustices, develop identity, and to participate in civic and educational opportunities. Youth who practice mindfulness, or pay intentional attention, to their social media practices can also increase their self-esteem and experience greater identity clarity (Yang et al., 2017). Additionally, developing a personal style in DSC can help women break down

stereotypes by demonstrating women communicate science in diverse ways (AbiGhannam, 2016). AbiGhannam (2016) examined the latter in her study of the experiences of women engaged in digital science communication. Her research revealed some interesting patterns in women's choices of communication style, which ranged from those who preferred more self-focussed science communication that allowed them personal escape and self-expression, to those who preferred more outward-focussed science communication to normalize or popularize scientific concepts (AbiGhannam, 2016).

That women are already underrepresented in STEM is certainly a part of the puzzle, but they may be further impeded by additional social and cultural factors in the digital realm (Fogg-Rogers, Sardo, Boushell, 2017; Sotudeh & Khosian, 2014). Even in technologically enabled countries like Canada, where women have access to the internet, we can still observe a "digital divide" in technology use between men and women (Conrad & Mullally, 2010; Shade, 2014). Shade (2014) argues that in the last decade there has been a shift in Canada's social and digital policy from promoting internet access for participatory citizenship towards using digital skills for commercial purposes. The latter is of concern in both the contexts of missed opportunities for promoting participatory citizenship through DSC and the lack of government intervention to address social issues arising from digital divides.

Traditionally, science communication has been viewed as a 'soft' or feminine skill (AbiGhannam, 2016) and women tend to participate in offline outreach (e.g. tutoring, giving presentations, school visits) more than men (Andrews, Weaver, Hanley, Shamatha, Melton, 2005; Sotudeh & Khoshian, 2014). However, somewhere in the transition from offline to online, women in STEM become the minority gender in science communication and the barriers they encounter go beyond issues of accessibility. Greenhalgh-Spencer (2017) argues that the lack of

women in digital fields is because the discourse within these fields creates female-unfriendly spaces. Using the concept of reproductive labour as a lens, she highlights the use of sexist and patriarchal language within the digital workforce and how this language normalizes women as "machines of sexual reproduction." Language examples include commonly used technical terms like *motherboard, daughterboard, generative programming*, and *clone*. Furthermore, female-unfriendly digital environments are also observed in social media and blog sites, where derogatory terms associated with female-ness (e.g. slut, bitch, fat, ugly, etc.) are used as an exclusionary tactic or to imply ineptitude (Greenhalgh-Spencer, 2017).

Tekobbe (2017) reiterates the idea that women are screened out of key collaborative roles in digital communities focussed on creating content (e.g. Wikipedia or Github), leaving them with more gendered online spaces, such as social media sites, in which women are the predominant users. However, Tekobbe (2017) also puts forward an interesting argument in her statement that "women's digital literacy competencies are measured first by their association with gender, then by their relative interest to a male audience, and finally by a skewed assessment of the value of the end result" (p. 394). Pinterest, for example, is a gendered online space that has been evaluated as a platform that supports women's online practices of 'sharing', which is evaluated as trivial and not 'real' content creation. Tekobbe (2017) claims that the latter is not the case and that Pinterest users demonstrate rich digital literacy practices by creating visually organized content that simply bypasses legacy script.

Addressing the Gaps

When it comes to interventions specific to increasing the representation of women in STEM using DSC, there is a significant gap in the literature. The majority of research thus far has

focussed on *how* and *why* women in STEM are using DSC but pays little attention to *what can be done* to increase their online representation. By building upon the existing knowledge of issues around women in STEM, and their use of DSC, this project contributes to the overall body of knowledge by exploring how PAR can be applied to identify the *"what can be done"* piece that is missing from the literature.

Conclusions from Literature Review

Understanding the current status of women in STEM and scientists' use of DSC contributes to our current understanding of issues around women's use of DSC. Robinson et al. (2015) claim "digital inequality and exclusion cannot be analyzed apart from the offline circumstances of individuals and groups and… specific forms of digital exclusion map onto particular offline disadvantages" (p. 570). With the latter in mind, I discuss below how some of the key challenges identified in the literature might inform decisions on interventions.

Foster a sense of community. As a minority both offline and online, women in STEM may struggle with feeling like part of the STEM community, particularly when they feel a competing sense of belonging in other fields (Thoman et al., 2014). Creating learning opportunities that help women advance their capacity in DSC *and* that develop a greater sense of community might contribute to women's retention in STEM. Also, as noted by Grand et al. (2016), creating communities of practices can help scientists to collaboratively work through the learning curves of new digital media and to motivate colleagues to take part in voluntary channels of communication. Group mentoring may also be a way to foster a stronger sense of community through increased STEM-related networking (Stoeger, Hopp, & Ziegler, 2017).

Increase in self-efficacy. Self-efficacy plays a significant role in the recruitment and retention of women to STEM (Falk et al., 2013; MacPhee, 2013) and is likely an influencing factor in their DSC engagement levels. Fogg-Rogers et al. (2017) argue that low perceived self-efficacy in public science communication can be increased through training and by fostering more support for public engagement within research environments. Therefore, interventions at both the individual and research lab levels might have a wider impact. Additionally, strategies to increase self-efficacy should consider not only how confident women are in using various digital media platforms but also how confident they are in creating *science communication content*, which varies depending on the audience (e.g. public versus peer to peer).

Remove digital media gender stereotypes. Creating female-friendly digital space may encourage women to contribute more to the creation of digital science communication content. However, acknowledging the technological literacy involved with creating content within female-dominated digital platforms (e.g. Pinterest or Instagram) and placing a higher value on the end results can empower women as content creators (Tekobbe, 2013). Encouraging women to explore ways to incorporate DSC into digital media they already use or prefer to use can also increase their awareness of the many creative ways they can contribute to the online discussions about STEM.

Chapter 3: Research Design and Methods

In this chapter, I seek to clarify how the PAR ideology applied to my project and how the ILD framework impacted the process. I discuss the key principles of PAR I considered in this project, including *collaboration, empowerment, and self-reflection, and action,* followed by details of why and how the ILD framework was applied, and how I approached some of the ethical considerations I encountered. Details of the methods employed by the research team are described under each stage of the ILD framework we included in the project*: (a) Orientation, (b) Survey literature, (c) Audience characterization, (d) Needs analysis, (e) Theory development,* and *(f) Initial design*. I conclude this chapter by discussing how the research team evaluated the research process, potential next steps, and some considerations around the final reporting of the project.

Participatory Action Research

Though there are various definitions of PAR, they are usually similar in nature. Cornwall and Jewkes (1995) define PAR as research that "focuses on a process of sequential reflection and action, carried out with and by local people rather than on them" (p. 1667). Alternatively, Baum, MacDougall, & Smith (2006) define it as "collective, self-reflective inquiry that researchers and participants undertake, so they can understand and improve upon the practices in which they participate and the situations in which they find themselves" (p.854). McTaggart (1994) goes a bit deeper and describes PAR as "a form of self-reflective enquiry undertaken by participants in social situations to improve the rationality, justice, coherence and satisfactoriness of a) their own social practices, b) their understanding of these practices, and c) the institutions, programmes and ultimately the society in which these practices are carried out" (p. 317). McTaggart (1994) also claims that PAR has both individual and collective aspects, where change takes place among the

researchers themselves and as the result of researchers working together to achieve and understand change at a broader more societal level. Central to all three of the above definitions are the ideas of collaboration, empowerment, self-reflection, and action, each of which I discuss in the context of my project in the following sections.

Collaboration. When I invited WISEST community members to participate in this project, I did so with the intent that research be conducted with and by them, rather than on them, a key characteristic of PAR (Cornwall & Jewkes, 1995; Herr & Anderson, 2005; MacDonald, 2012; Stringer, 2014). This breaks from traditional forms of research where participants are the subject of study and contractually recruited to take part in a researcher's study (Cornwall & Jewkes, 1995). PAR is a process of mutual and collaborative inquiry, in which individuals reach an intersubjective, non-coerced agreement about what to do about a situation (e.g. lack of women using DSC) (Hawkins, 2015). Though I initiated this research, and each person involved took on a slightly different role, I chose to involve the WISEST research team as co-researchers – making this "our" research project, rather than "my" research project (Hawkins, 2006).

Empowerment. Involving the WISEST research team as co-researchers was a strategic decision I made grounded in the belief that it offered them the opportunity for both individual and organizational empowerment. Individually, participants were empowered by taking an active role in developing WISET programs and taking ownership over their own DSC practices, and organizationally, WISEST was empowered by deepening their knowledge in an area that impacts their target audience and by expanding their capacity to offer outreach programs for women in STEM (Ruechakul, Erawan, & Siwarom, 2015). Involving individuals and organizations in research has real implications to practice, where new knowledge can initiate organizational change and improve an organization's ability to meet community demands (Baume, et al., 2006).

I agree with McTaggart's (1994) claim that PAR helps practitioners (e.g. those who do work for WISEST) by increasing their confidence and knowledgeability in ways that influence their practice.

Self-reflection. The incorporation of self-reflection into PAR is important for enabling the processes of collaboration and empowerment described above. It allows participants to critically examine their own practices and knowledge, and the social structures that constrain their practices (Atweh, Kemmis & Weeks, 1998). Throughout the project, participants were encouraged to think about their own experiences and how this influenced their interpretations of data, preconceptions, and their own practices. Personally, I committed to keeping a learning journal, so that while documenting the research process, I could reflect on how my own experiences and interpretations came into play or influenced how I participated in the research.

Action. As discussed in the sections above, the ultimate goal of our project was to use the PAR process as a means to design – and eventually implement – interventions to encourage more women to engage in DSC. This was the "action" component of the PAR process we were striving for. We were not researching just for the sake of creating new knowledge, but for opportunities to infuse knowledge into actions with the potential to catalyze real change.

PAR is an iterative process, characterized by cycles of looking, thinking, and acting and after each cycle, the impact of the action is evaluated, adjustments are made, and the cycle repeats (Stringer, 2014). Our research project was just part of what could become potentially many cycles, especially if WISEST continues incorporating new knowledge and interventions into their work. These cycles often occur naturally in the development of educational programs because these usually end in an assessment of the program's impact (Bannan-Ritland, 2003;

Richey and Klein, 2005). Thus, I turned to educational research strategies to determine the best way to move this project forward.

Developmental Research

In the end, I adopted a developmental research *framework* to help guide the research process. Richey and Klein (2005) describe developmental research as the study of designing, developing and evaluating instructional programs, processes or products, which can either create generalizable conclusions or solve context-specific knowledge to address a problem. They claim developmental research "seeks to create knowledge grounded in data systematically derived from practice" (Richey and Klein, 2005, p. 24). Similarly, Cennamo (2003) describes instructional design as "a process of knowledge construction, involving reflection, examining information at multiple times for multiple purposes, and social negotiations of shared meanings" (p. 13). Edelson (2002) claims that "In the traditional theory-testing paradigm, design and research are distinct processes that happen sequentially," but now, "design research explicitly exploits the design process as an opportunity to advance the researcher's understanding of teaching, learning, and educational systems" (p. 107). Therefore, the process of design itself is used to advance knowledge and understanding, while simultaneously erasing the line that historically separates design and research (Edelson, 2002).

Though developmental research can vary in process, there are often notable similarities among designs. Richey et al. (2014), describe the developmental research process as consisting of four phases: (*a) Design, (b) Development, (c) Utilization and Maintenance, and (d) Impact and Final assessment*. Their process is similar to Bannan-Ritland's (2003), called the 'integrative learning design' (ILD) framework, and which also consists of four phases: *(a) Informed Exploration, (b) Enactment, (c) Evaluation: Local Impact, and (d) Evaluation: Broader Impact*. I

chose to adopt Bannan-Ritland's (2003) framework to guide my research because its intent to "provide a comprehensive, yet flexible, guiding framework that positions design research as a socially constructed, contextualized process for production of educationally effective interventions with a high likelihood of being used in practice" (p. 21) resonated with my personal values and what I hoped the project would achieve.

Applying the ILD framework to my project gave myself and the WISEST research team a basic process to follow on our quest to learn more about how we could help more women in engage in DSC. It guided us to a deeper understanding of the issue we were considering and to potential interventions derived from a critical examination of what we learned during the design process.

Due to limited time, I focused my project on the 'informed exploration' and initial design section of the 'enactment' stage of the Bannan-Ritland's (2003) ILD framework. Working through these stages involved developing a collaborative understanding of the overall problem by conducting a literature survey, characterizing our audience, assessing our audiences' learning needs, and completing the initial design of interventions. (Bannan-Ritland, 2003). I slightly modified the ILD framework (Figure 1) by adding an orientation stage to ensure all participants had a solid understanding of the issue and the PAR process. It also served as an opportunity to discuss our roles and establish project goals.

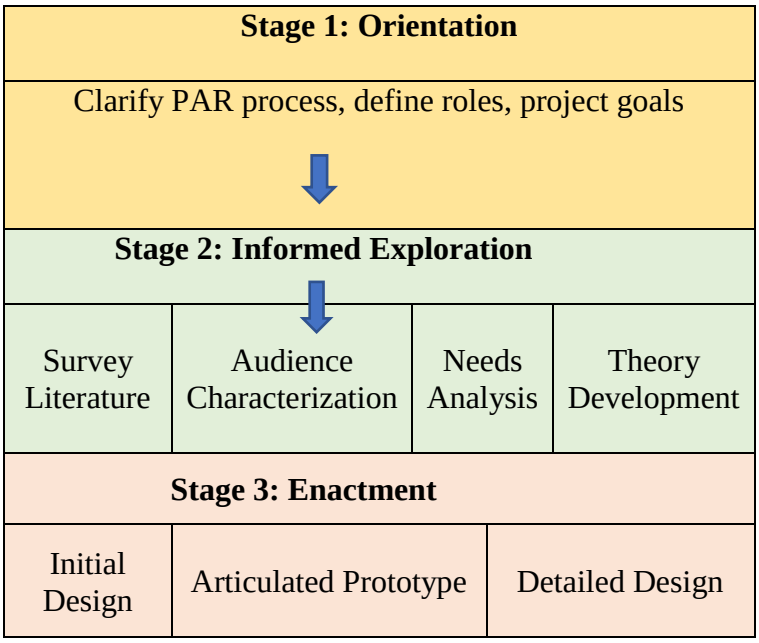

Figure 1: A modified version of Bannan-Ritland's (2003) ILD framework I adopted to guide the design process for my research project. The WISEST research team collaboratively decided on strategies they wanted to use to complete each phase of the framework.

However, the ILD framework did more than just guide us through the design process. It helped us meet the demands for more prescriptive research to address the needs of a certain group of people (Richey and Klein, 2005) – women in STEM. Even though the interventions designed by the research team target women at the localized level of WISEST, they were developed in response to the broader social issue of too few women engaging in DSC. I argue that it's logical to address large social issues at the local level first and when these efforts are multiplied they can have a positive and far-reaching impact.

Ethical Considerations in Participatory Action Research

This project was grounded in the idea that PAR acquires knowledge through a participatory process rather than through doing research on the participants (Herr & Anderson, 2005). My intent was to evaluate the PAR process, not my participants, so the University of Alberta Research Ethics Board (REB) deemed the project out of scope for REB review. However, reaching this understanding and confidently moving the project forward was challenging because even though PAR does not always fit into the scope of traditional REB review, there are still ethical implications to consider throughout the process.

The ethical obligations for researchers to do no harm and to respect the people involved and affected by the research stems from more positivist research, often those involving clinical trials and human subjects (Herr & Anderson, 2005; Kemmis, McTaggart, & Nixon, 2014). However, this also extends to qualitative research and though PAR is qualitative in nature, it differs in that research is conducted *with* participants rather than *on* them (Smith, Rosenzweig, & Schmidt, 2010). Also, things like methods and data-gathering strategies are negotiated by the research team throughout the process, and therefore cannot be pre-determined for REB review. Herr and Anderson (2005) note that REBs vary in how comfortable they are with PAR, but most use guidelines better suited for more traditional forms of research.

There is no one way to overcome these challenges, but one strategy I used to address them was to clearly define my role in the process before we started, which I discuss in more detail below.

My role in the research process. Some researchers treat PAR participants like those in traditional qualitative studies, where they interview or observe them to generate data (Smith et al., 2010), but this was not the case for me. My role was that of a "facilitator" over that of a "researcher." Rather than focussing on quick, extractive data collection, I adopted an approach similar to Hawkins (2015), in which I facilitated the WISEST research team in producing and analyzing their own data. An advantage of assuming the role of a facilitator is that it gave me the ability to foster a collaborative environment of respect and to suggest strategies or processes to maximize individual and organizational empowerment (Hawkins, 2015).

In some ways, being a facilitator limited my involvement in the project because I had to be mindful to stay within the bounds of my role. The point at which a research project requires REB review is not a clear one, prompting me to frequently consider my scholarly obligations and interests and how these fit into a project where I was not the principal investigator. The WISEST research team determined the methods and gathered their own data and I had to be careful to ensure my actions did not involve any independent data collection. This was surprisingly difficult to do when you are involved in a research project you feel passionate about. However, it was my job to understand the ethical complexities of PAR and to ensure the process unfolded in a respectful and ethical way for all those involved.

I also had to consider how my role positioned me within the research project itself. Herr and Anderson (2005) argue that PAR researchers need to be clear about their relationship to the setting they are studying because how they position themselves, as either outsiders or insiders, influences how they frame epistemological, methodological, and ethical issues. The positionality I identified with the most was that of an "outsider" because I had no authority or formalized affiliation with WISEST when I initiated the project. I approached WISEST because of my own

personal interest in women's use of DSC and my desire to explore it through scholarly research. However, my position was complicated by the fact that I had a history with WISEST and was connected to them through previous employment. It could be argued that the latter point, in conjunction with my own capacity as a woman to engage in DSC, also gave me a kind of "insider" status. As such, I feel it is important to acknowledge how my own thoughts and reflexivity contributed to both the facilitation of the project and my interpretations because failure to do so is deceptive and would exclude the self-reflection component that is integral to good practitioner research (Herr & Anderson, 2005).

To accurately capture my thoughts, I kept a digital “learning journal,” where I recorded my reflections and interpretations of how the PAR process was going, a practice often encouraged in action-based research (Stringer, 2014). This was a helpful tool for recording thoughts and ideas and making notes for key items to report on at our meetings.

Informed consent. Even though I was not bound by REB procedures, I felt it was important to ensure all participants were clear on their voluntary status and their right to withdraw from the study at any time, so I provided them with an informed consent form (Appendix B). However, it’s important to note that as Herr & Anderson (2005) argue, “The informed consent procedure does not adequately capture the dynamic nature of the evolving research procedures and relationships,” (p. 119), particularly as required for REB approval. This is because unlike traditional qualitative studies, where methods are predetermined before participants engage, methods in PAR studies are negotiated by the research team and often evolve during the process (Herr and Anderson, 2005). In some cases, even the research question or purpose of the study are not defined until they have been collaboratively negotiated by

participants. I was careful to indicate in the form that I was a facilitator and that it would be them who determined the methods applied to the study.

Despite the challenges around PAR and informed consent, the deeply collaborative process and negotiation that occurs among participants can mitigate this. Herr & Anderson (2005) support the argument that the ongoing dialogue and decision making between PAR participants is a kind of processional consent, a concept I was mindful of as I helped the research team make decisions on how they would move forward. I asked them to discuss and choose their research strategies and followed up on our meetings with emails and notes outlining the agreed upon next steps, inviting feedback and suggestions at numerous points.

Qualitative safeguards. Another aspect of PAR that is challenging from a traditional REB perspective is the potential to compromise the qualitative safeguards typically required in academic research. This includes things like anonymizing data and protecting the identities of participants. Because PAR works in such a localized setting, identities can be implied in reports, making this difficult to address (Herr & Anderson, 2005). I outlined this concern in the informed consent form and gave participants the opportunity to ask questions or withdraw from the project. Upholding the PAR ideal of respect and being mindful of how I reported team members involvement was a strategy to maintain qualitative safeguards wherever possible.

Many PAR practitioners claim the evolving nature of PAR requires a constant re-evaluation of how ethics can be incorporated into the project (Herr & Anderson, 2005), advice I considered throughout the duration of the process. For example, even though WISEST research team members were responsible for data collection and analysis, I recommended all survey data be anonymized before sharing it with the research group. We also discussed who would store and share the data, which ultimately belonged to WISEST.

Methods

Forming the WISEST research team. After seeking approval from the senior WISEST staff and their executive board, I created an invitation to participate in the project (Appendix A). After discussions with WISEST staff, we decided to share the invitation with a select number of staff, board members, volunteer committee members, and UA-Wise and Wiser executives to ensure participants came from an engaged pool of individuals. These were women in STEM who were already familiar with WISEST, passionate about their mandate, and who were likely to commit for the duration of the project. Being selective of whom we invited also meant we could target women who could potentially benefit from PAR by learning how to enhance their own DSC practices and by increasing their personal confidence and knowledge (McTaggart, 1994).

In total, fourteen invitations were sent out and four individuals volunteered to participate. My initial hope was to recruit at least six women but to keep the project on time I made the decision to continue. Also, because WISEST has a large student community and it was near final exam time, many invitees were not available. Had this project not been bound by the timelines of my master's program, I might have chosen a different time of the year to initiate it.

The four confirmed participants came from diverse backgrounds and included two WISEST staff, each with a master's of science and several years experience in coordinating and delivering various science-related community outreach programs, a professional civil engineer, and a science centre program coordinator with a degree in science education. The non-staff team members had a strong history of volunteering with WISEST and were familiar with their programs and overall organizational vision and mission.

When undertaking a PAR project, it is important to establish an environment of respect and trust, where all team members are valued and treated with dignity and respect (Hawkins, 2006; Stringer, 2014). Therefore, I wanted to make it clear that participation was completely voluntary, and each team member could contribute and express themselves freely. Prior to meeting, each participant was given an information letter and the previously mentioned consent form (Appendix B) to help them better understand the project and what would be required of them.

Research timeframe and process. The scope of the project included in this report took place over two months. Initially, I asked participants to commit to a four to five-week period, but this was difficult to guarantee because research methods had to be determined by the team. In the end, there were three face-to-face meetings supplemented by remote between-meeting work, a schedule negotiated by the team based on their availability and the type and amount of work to be done. During each meeting, the group collectively decided how to move through each phase of the ILD framework, including decisions on what information or data to collect and how they would acquire it. Details of each phase are outlined below.

Orientation. As mentioned, the orientation was an opportunity to further introduce team members to the issue and the PAR process. Prior to meeting, I provided all team members with a slide deck about PAR, a draft of the literature review included in this report, and an orientation agenda. It is important to note that I did not intend to provide a literature review to satisfy the "survey the literature" phase of the ILD framework (Figure 1), but rather I provided it as a starting point for the team to build upon as the PAR process unfolded. Some scholars, like Rai (2003), take the position that texts and literature should not be introduced into the PAR process until participants have had a time to tell their own story and develop their own agenda, but

because this project was situated within a framework requiring a literature review and had a condensed timeline, I felt it was appropriate to share this. Participants were free to make their own interpretations and to share their comments. Furthermore, all information I gathered during my review was from databases that were accessible to the team so in support of promoting a collaborative environment, I felt research team members should not be excluded from the work I had already done.

Introducing the team to the proposed research framework was also an important part of the orientation meeting. It gave me an opportunity to describe how Bannan-Ritland's (2003) ILD framework could be applied to the project and how it would serve as a flexible, guiding tool that would allow them to define their own goals and methods to apply to each phase.

During this initial meeting, the team engaged in a passionate discussion about the issue, often referring to their own experiences using digital media and engaging in DSC, demonstrating how naturally self-reflection can integrate into the PAR process. They identified what they believed to be the key contributors to so few women engaging in DSC, the overriding reasons they felt it was important to address the issue, and some preliminary ideas of what interventions could look like. They also defined their project goals, which included gaining a better understanding of the barriers women face in engaging in DSC and increasing their own knowledge of how they could address these barriers. As a result, the team formulated the research question, *"**What are the barriers WISEST participants face in becoming more engaged in DSC?"***

***Surveying the literature*.** In addition to the traditional literature review I provided, the research team decided to expand on this phase in two ways. The first was to have WISEST staff pull together a brief environmental scan so non-staff research team members could better

understand WISEST's organizational structure, programs, digital media practices, and opportunities to integrate interventions that promote DSC into their own programs and practices. The second was to conduct individual online research, which involved looking at successful digital science communicators. Though their focus was to look at women, the team decided not to exclude men from their review because they might see differences or qualities worth noting.

Audience characterization. To complete the "audience characterization" phase of the ILD framework, we opted to use our literature review findings to help describe "the ideal female digital science communicator." The research team felt building a persona or visual representation of a successful digital science communicator would help demystify these women for WISEST participants and build a DSC 'role model.' Each member conducted her research in her own way, some using basic internet searchers to find lists of recommended female science communicators online, and others searching via well-known science hashtags like #WomeninSTEM and #distractinglysexy. This work was conducted remotely, and research team members collaborated by sharing their findings via Google Docs before discussing at our second face-to-face meeting.

The audience characterization phase of the ILD framework is similar to persona development approaches often used in technology design or marketing strategies. The latter use qualitative data, such as that derived from interviews or observations, to depict user behaviour and attitude to help make design decisions (Miaskiewicz & Luxmoore, 2017). Our strategy slightly differed in that the group did not characterize the end user (e.g. our target audience), but rather chose to describe the characteristics we wanted women to have as a *result* of programs or interventions the team designed. I argue this was a valid approach within the ILD framework because information about the target audience is captured within the needs analysis phase and

being creative with how you characterize your audience can open up new ways to design interventions.

While the research team conducted their characterization work I encouraged them to start considering what areas they would want to measure in the needs analysis phase of the ILD framework. I provided them with resources on coding qualitative data and tasked them with identifying the key themes that emerged from their orientation meeting discussion, literature review, and audience characterization research. These themes would serve as the broad areas, or "pillars", they would measure when evaluating their audience's DSC learning needs. Findings were shared in the Google Doc with their audience characterization work and preliminary survey questions that emerged from their research.

Developing the pillars was a "muddy," process and though undertaking the work remotely was a good way to start compiling ideas and observations, I felt the team was struggling with identifying clear themes and potential areas to assess in their needs analysis. Miaskiewicz and Luxmoore (2017), argue personas derived from qualitative research can be difficult because the people examining the same qualitative data can develop different personas. However, I would argue PAR helps to overcome this because its collaborative nature supports consensus building, which was evident in our next face-to-face meeting.

During our second meeting, I compiled characteristics observed by the team and individually wrote them on post-it notes before asking the team to sort them into categories on a whiteboard. It was rewarding to see the collaborative aspect of PAR effectively move the team forward. By working together and negotiating their interpretations of their research, the group was able to map out and categorize their data into four themes, or "pillars" (Table 1): *(a) Communication skills, (b) Scientific knowledge, (c) Motivation, and (d) Digital literacy*.

Communication skills included characteristics related to an individual's ability to engage with an audience, such as their style and ability to break complex ideas down for a lay audience. Scientific knowledge included things like how informed or knowledgeable an individual is in their subject area. Motivation encompassed how passionate an individual was about STEM and their willingness to commit time to DSC and digital literacy referred to their technical skills in using digital media and the various levels at which they use it for different purposes.

Table 1: The four main themes and their defining characteristics, as identified by the research team in the literature review and audience characterization phase of the ILD framework.

Communication Skills	**Scientific Knowledge**	**Motivation**	**Digital Literacy**
Charismatic Interacts with audience Has a style Confident Makes the mundane interesting Thick skin Confident Can break complex ideas down for a lay audience	Credible Knowledgeable Well informed Stays current in what is attracting scientific and popular attention	Passion for STEM Loves knowledge sharing Makes time to commit to their communication	Can use multiple platforms Comfortable with the digital media they use Use digital media to demonstrate ideas or concepts Consistent in delivering high-quality, interesting material Uses digital media for networking Supports female science community

Needs analysis. Like other phases of the ILD framework, the research team had flexibility in selecting the methods to conduct their needs analysis. However, due to time considerations, an online survey was deemed the most appropriate.

With the four pillars listed above in mind, the group started to examine the "gaps" in what we knew about our target audience and to formulate survey questions. First, I walked the research team through a Characterization Checklist (Appendix C) exercise from a resource I found from the U.S. Department of Commerce's National Oceanic and Atmospheric Administration ('Needs Assessment Guide,' 2018, April 1). It was my intention that this step help identify areas the team needed to understand better and to identify potential survey questions, but we approached this exercise more as a tool to stimulate discussion than as a formal part of the process.

Next, the group worked collaboratively to draft survey questions that would gather key demographic information and measure how their audience performed or felt about each of the four pillars. Referring back to the four pillars and the characteristics within each was helpful in keeping the group focused on what they wanted to include in their needs analysis and to help them achieve their goal of a brief survey. Though the bulk of the questions were drafted at the meeting, finalizing questions and putting them into an online web form was conducted remotely by WISEST staff members.

Once ready, the voluntary survey was distributed as per WISEST's own organizational policies and procedures to a mailing list of approximately 5000 recipients. All data was stored by WISEST and anonymized before sharing with the remainder of the research team for analysis. Within one week 129 responses (108 female and 19 male) were collected, exceeding the team's

minimum goal of 100. The research team worked remotely to sort and summarize assigned sections of data and then collectively analyzed and interpreted it at our final meeting.

The team felt the data reinforced what they already knew or had learned from their previous work, but they were also able to identify some interesting trends. For example, almost 50% of the women who responded said they did not follow any digital science communicators online and even though women felt confident in using digital platforms, they did not feel confident in their scientific knowledge. The majority of women found their field of work or education interesting and saw the public and personal benefits associated with DSC, but most were still not engaging in DSC. This repeatedly brought the team back to the pillar of motivation and discussions around what were the most important and effective motivators for engaging women.

Theory development. The theory development phase of the IDL framework took place at each step of the research process. As the team gathered information they individually and collectively interpreted its meaning and built 'theories' about why women don't engage as frequently as men in DSC. The process guided them from theory building at the broader level of all women's use of DSC to the more focused level of their target audience.

Moving through the ILD framework supported the beginnings of 'grounded theory development', which Corbin and Strauss (1999) say involves the systematic and sequential collection and analysis of data important to the understanding of the topic, captured by the research process. Corbin and Strauss (1999) also say the following:

> The procedures of grounded theory are designed to develop a well integrated set of concepts that provide a thorough theoretical explanation of social phenomena under

> study. A grounded theory should explain as well as describe. It may also implicitly give some degree of predictability, but only with regard to specific conditions. (pg 5)

With this definition in mind, I would argue the process that unfolded during our project helped the research team develop theories on how to increase their audience's engagement in DSC. These theories are evident in the initial intervention design described in the following sections.

Taber (2000) claims grounded theories should be testable, which can ultimately support the predictability of a theory, but the scope of this project did not include testing. We were limited to the first stages of the design within the ILD framework and unfortunately did not formally implement or evaluate interventions.

However, I argue interventions can serve as instruments for theory testing (Taber, 2000). For example, a theory that women who find and cite credible scientific sources are more confident in communicating science can be tested by implementing and evaluating an intervention designed to increase women's skill in finding and citing good sources. Over time, compiled evaluation feedback can potentially support the predictability of the theory, especially when using a process such as the ILD framework. Like, Stringer's (2014) 'look, think, act' action research cycle, the ILD framework can be cyclical because once an intervention is implemented, the cycle can begin again. This gives researchers an opportunity to look and think about the impact of their action before repeating the process and gives them time to evaluate how effective their action is in creating change. However, as Corbin and Strauss (1999) state, this may be limited to a certain set of conditions (e.g. age group or demographic).

Initial design. With the data analyzed, basic theories and explanations developed, the research team moved into the initial design phase of the ILD framework. This was the stage where the researchers started to formally consider how their findings and initial theory development could inform potential interventions or educational strategies. However, it would be misleading to say the initial design was limited just to this part of the research process. From the very first meeting, research team members began to formulate interventions, either by sharing via the Google Doc referenced earlier, formulating ideas on how to change their personal practices, or by examining how WISEST could integrate some simple changes into their own DSC practices to encourage more women to engage. Initial ideas included things like incorporating Instagram challenges into WISEST's summer research program for grade 11 girls and plans to enhance their organizational social media presence. At one point during the research process, WISEST streamed YouTube videos of women in STEM to school-aged youth and presented their work on engaging more women in DSC at a national conference. Though these initiatives were not a formal part of the research process they were *actions* linked to the researchers' new knowledge and desire to promote change.

The formal initial design phase took place at our final meeting and was part of a data analysis exercise I prepared for the team. This involved summarizing an "unhappy," or unengaged, digital science communicator and a "happy," or engaged, digital science communicator under each of the four pillars we identified and then brainstorming interventions or strategies that could move the unengaged into the engaged category. The team used survey data supplemented with knowledge developed from their literature review and audience characterization to fill in a three-column chart (Appendix D).

This exercise was helpful in two ways. The first was it allowed the research team to see how their survey informed them about their audience in each of the four key areas they had identified. Once the chart was populated it was clear they had a good amount of data on the motivational issues influencing women's engagement (e.g. lack of time, not seeing professional benefits, etc.) but very little data on what contributed to the varying levels of confidence in their scientific knowledge and communication skills. The second was the chart illustrated which pillars the research team was able to generate the most interventions for. The pillars of motivation and digital literacy generated far more initial design ideas than scientific knowledge and communication skills, which may have been due to a lack of data in these areas. Using examples from the data analysis exercise (Appendix D), I discuss below how the research team used the chart and active discussion and negotiation to complete their initial intervention design for each pillar.

Motivation. The research team identified the less motivated people as those who did not see the value in DSC for the amount of time they had to invest in it, or who felt DSC was not appropriate or required for their jobs. These people were more likely to feel their work was not interesting or were not currently following science communicators online. Alternatively, the research team felt motivated individuals recognized the professional values of DSC or enjoyed engaging with the public. They were also more likely to feel their work was interesting and therefore more motivated to share it.

Interventions in this area focussed on helping women overcome time barriers and to better see the value in engaging in DSC. These included things like the creation of user-friendly 'how-to" guides to reduce learning curve time commitments, encouraging the use of private versus professional social media accounts, connecting women to DSC role models, creating lists

of digital science communicators to follow, and developing strategies to help women communicate the relevance of their work.

Communication skills. The team felt lack of confidence was the key limiting factor for women in this area. They concluded the fear of negative feedback, or of being seen as less credible than men, was impacting women's communication skills. Therefore, they felt increasing communication skills could potentially boost confidence. Initial intervention included ideas like teaching women how to find credible sources to back up their DSC, educating them in personal style or branding techniques, teaching them to use narrative in STEM communication so they have more confidence in their style, and helping them to better communicate the relevance and impact of their areas of interest or expertise.

Scientific knowledge. When considering how scientific knowledge influenced women's engagement in DSC, the research team concluded the fear of being misunderstood or not feeling like an expert were key factors. An important consideration they identified was that early career women, or those still in high school and early university years, were likely not as confident in their scientific knowledge as those in the more advanced stages of their education or career. Initial intervention ideas included things like reinforcing the fact that women had time to research before posting scientifically sound information, conducting exercises in critical thinking to help individuals better assess the content they share or create, and helping women identify unreliable versus reliable academic and scientific sources.

Digital literacy. The research team identified lack of confidence in using digital platforms as another key barrier to women not engaging in DSC. They felt there was a disjoint between how women consumed and produced content. For example, many women consumed DSC as a learning tool but were not confident in producing their own content. The research team

also concluded women who were not following other digital science communicators may have lower digital literacy because they were not familiar with the ways they could use various digital media to communicate.

An interesting decision the team made in this pillar was to identify digitally literate women who engage in DSC as those who actively support the online female science community. They felt women with higher levels of digital literacy used things like hashtags, links, and tagging to effectively promote their fellow female science communicators, contributing to a stronger online female STEM community. Less digitally literate women may not have the knowledge of how to use some of these digital techniques.

Initial interventions included educating women in a variety of platforms to demonstrate the diverse uses of digital media, challenging women to follow new or more digital science communicators so they could see what others are doing, creating weekly digital media challenges to consistently engage women in trying new platforms, and creating a blog or online community where women could feel safe exploring digital content creation and potentially have role models or other community members give feedback on their work.

Evaluation of the research process. Collectively, the group felt the interactive and collaborative research process was effective. The process helped them identify interventions they would not have previously known about and to better target their audience during the initial design phase. They also recognized the personal and professional implications their involvement in the project had because they felt their own DSC practices were likely to change as a result of their new knowledge and participation.

However, the research project was not without its limitations. All agreed that lack of time, particularly for data analysis, was the most significant limitation. Information gathered in their needs analysis was from quite a broad audience, with respondents ranging from high school age to over 65 years and the team did a very basic analysis of their data. However, the amount and depth of data they collected was seen as a future resource for WISEST because they could revisit their dataset and drill down to look at specific demographics on an as needed basis.

Another limitation was the slight disparity in the amount of data collected for each of the four 'pillars.' As mentioned, their analysis revealed quite a bit of information about what motivated women to engage in DSC but was lacking information about what contributed to their level of confidence in general science knowledge and communication skills. Piloting or adjusting future survey questions could potentially help to avoid gaps in the data set but an advantage of using the ILD framework was it also generated knowledge in the literature review and audience characterization staged, helping to fill any gaps before commencing the initial design stage.

Next steps. The articulated prototype and detailed design phases of the ILD framework are the next logical steps for the project but are not included in the scope of this report. These phases will involve refining initial design ideas into actual learning or intervention resources, such as a workshop curriculum or an online community developed to support women in DSC. The research team identified several opportunities to begin implementing interventions and were discussing how to incorporate these into new and existing programs.

Final reporting. As for final reporting, the research team felt the archive of meeting notes and data was sufficient until they could implement and evaluate some interventions. They saw more value in doing their final report as a presentation rather than a report, so they could share their work and findings with the WISEST community and other stakeholders. This itself

serves as an intervention by helping to raise awareness about the issue of women not engaging in DSC and demonstrating how PAR can be used to make informed decisions on actions taken to address social issues.

Smith et al. (2010) claim because PAR is co-created by a team, all participants have a shared interest in the process and outcomes of the project but may have differing interests in other areas. For example, I had the obligation to produce a capstone report on the project whereas the other members of the research team did not. Therefore, the ability for me to co-author this report was limited, though I did my best in my summary above to include the perspectives of the research team by describing the rationale behind their decisions, which were inextricably linked to the process. Additionally, there are other opportunities for participants to add their voice to reporting on PAR projects (Smith et al., 2010; Van der Meulen, 2011). In our case, this included participants co-presenting with me at a national conference and tentative plans for future conference presentations. This is largely why the group considered a slide deck a useful way to conduct their reporting. Helping the researchers develop their knowledge and capacity to present on our research is a significant outcome for the project. It supports the PAR principle of empowering participants, reflected in MacTaggart's (1994) statement that individuals involved in action-based research note it, "enhanced their practice, confidence, knowledgeability and influence in their worksite," (p. 325).

Chapter 4: Conclusion

Continuing to encourage more women to engage in DSC is important because boosting their online presence can contribute to the solving the overriding issue of women being underrepresented in STEM. It also provides women with important networking and professional benefits and gives them opportunities to increase scientific literacy among the public. That there are fewer women online talking about science is undisputed in the current literature, but examinations into *what can be done* about it are lacking.

The PAR process and ILD framework applied in this project helped the WISEST research team collectively generate new knowledge developed explicitly to fill the gap in the literature. Their research examined how women from their target audience currently engage in DSC and identified key barriers they encounter in the areas of motivation, science communication, scientific knowledge, and digital literacy. Using this new knowledge, research team members were able to collaborate in the initial design of interventions to strategically address the barriers they identified. Participants were positive in their evaluation of the research process and as a result, are considering or already implementing changes to their personal or organizational DSC practices.

Adopting a PAR approach for this project meant there were numerous ethical and procedural complexities that had to be considered to meet both the project's goals and my capstone requirements. Of particular note, is the requirement for academic rigor in scholarly work and how this looks from a PAR perspective. In the following sections I discuss an alternative way of academically evaluating this project by using validity criteria recommended by Herr and Anderson (2005).

Redefining the Academic Evaluation of PAR

Due to the academic context in which this project took place, it's important to discuss the implications of evaluating PAR from a scholarly perspective. The differences between PAR and more traditional perspectives of academic evaluation are key contributors to many of the complexities I experienced in taking on this project. Of particular importance, are the ideas of reliability and validity of research, because the framing of these can influence the academic evaluation of a PAR project.

The reliability and validity of PAR and other action-based research methods is often a point of debate among academics. According to Golafshani (2003), reliability and validity stem from positivist traditions. From a quantitative perspective, reliability refers to the extent to which results can be replicated and validity addresses whether the, "means of measurement are accurate and whether they are actually measuring what they are intended to measure," (Golasfshani, 2003, p. 599). However, these concepts are still often applied to naturalistic qualitative studies, though many scholars conceptualize them as the trustworthiness, rigor, and quality of whichever qualitative paradigm they are working (Golafshani, 2003). Needless to say, there are many varying definitions among the qualitative paradigms, including PAR, which encounters additional challenges because it is a relatively young research approach and can significantly vary in process.

A key challenge for academics around the reliability and validity of PAR is how these relate to 'knowledge generation.' The strong link between PAR and professional practice means knowledge is generated by the 'insider' practitioner rather than the more traditional academic 'outsider,' who is often viewed within academia as more likely to produce reliable results (Herr & Anderson, 2005). Though the premise of PAR promoting social change is easy to argue, the

broader application of knowledge produced from PAR may leave some skeptical, as reflected in Herr and Anderson's (2005) following claim:

> Academics tend to be comfortable with action research as a form of local knowledge that leads to change within the practice setting itself, but are less comfortable when it is presented as public knowledge with epistemic claims beyond the practice setting. (p. 52)

Despite PAR's link to a localized setting, I support the argument that PAR ideals and practices mitigate the concerns of it not having the same academic rigor as other qualitative paradigms. One such way I already touched upon was how the continuous cycles of PAR reinforce theory development and predictability. PAR can produce testable theories, which can be evaluated across a variety of contexts, such as using educational interventions to test theories by implementing and evaluating them across a variety of educational contexts. Though I think it's fair to ask what benefit would there be in generalizing these theories in a radically different context? In our case, programs designed to help women engage in DSC might not be appropriate for different groups like male STEM professionals (though there may be some overlap).

Clearly presenting the rationale for choosing a PAR approach and defining its outcomes can also address some of the questions around its reliability and validity (Herr and Anderson, 2005). Helskog (2014) presents the argument that those who practice action-based research are often tasked with justifying their research, and to some extent, this means convincing others of its validity. How researchers go about justifying their work varies and Herr and Anderson (2005) make a similar argument in their idea that the validity of PAR should be evaluated based on a different set of criteria than more traditional forms of research. They suggest five key criteria, linked to some key goals of PAR, as outlined in Table 2 (Herr & Anderson, 2005, p. 55).

Table 2: Goals of action research and Herr and Anderson's (2005) recommended criteria.

Table 4.1 Anderson and Herr's Goals of Action Research and Validity Criteria

Goals of Action Research	*Quality/Validity Criteria*
1) The generation of new knowledge	Dialogic and process validity
2) The achievement of action-oriented outcomes	Outcome validity
3) The education of both researcher and participants	Catalytic validity
4) Results that are relevant to the local setting	Democratic validity
5) A sound and appropriate research methodology	Process validity

Note. Reprinted from "*The Action Research Dissertation"* by Herr, K. & Anderson, G., 2005, p.55. Copyright 2005 by Sage Publications.

I support the idea of redefining how PAR projects should be evaluated by academia because as the adage goes, 'one shoe does not fit all' and I believe Herr and Anderson (2005) have accurately represented the key goals of PAR in the above table. Within the context of our project, I briefly discuss each of these validity criteria.

Outcome and catalytic validity. In the case of our project, I feel the outcome and catalytic validity criteria should be discussed together because I see them as being inextricably linked. Outcome validity refers to the extent to which action occurs as a result of the project, contributing to the resolution of the problem that initiated the research to begin with (Herr & Anderson, 2005). However, Herr and Anderson (2005) concede it is difficult to define what makes the outcome successful because success can be subjective. They also claim outcome validity, "forces the researcher to reframe the problem in a more complex way, often leading to a new set of questions and problems," (p. 55). Catalytic validity, on the other hand, refers to the

degree the research process helps participants reorient their way of knowing reality and moves them towards taking action to change it (Herr & Anderson, 2005).

This report does not encompass the final outcomes of the project, which would be the result of the final interventions WISEST implements, but the catalytic, or action, component of PAR was visible at both the individual and organizational levels. At the individual level, participants were able to use their new knowledge to change their own practices, aligning with McTaggart's (1994) statement below:

> Action research has an individual aspect – action researchers work with others to achieve change and to understand what it means to change. Action research involves participants in planning action (on the basis of reflection); in implementing these plans in their own action; in observing systematically this process; and in evaluating their actions in the light of evidence as a basis for further planning and action, and so on through a self-reflective spiral. (p. 317)

At the organizational level, WISEST began adapting their own DSC practices very early on in the PAR process. This action is linked to the organizational empowerment WISEST experienced from participating in this project. Their new knowledge in DSC initiated organizational change based on their desire to better meet their audience's needs (Baume, et al., 2006).

Even though we did not implement interventions, the catalytic response of participants was evident from very early on in the process. Research team members were energized by their new knowledge and were considering or implementing changes to their personal or

organizational practices, which in my view are ‘catalytic outcomes’ arising from the PAR process.

Process validity. Herr and Anderson (2005) describe process validity as, “the extent to which problems are framed and solved in a manner that permits ongoing learning of the individual or system,” (p. 55). They argue for a process of reflection that continuously loops back to re-examine a problem and note that process validity must also consider what counts as evidence when making conclusions (Herr & Anderson, 2005).

Triangulation of methods, including things like observations, interpretations, and participant confirmation, contribute as validators in PAR (McTaggart, 1994). Furthermore, triangulation in PAR should include interpretations derived from the diverse perspectives of the participants (Herr & Anderson, 2005). In our case, I argue the ILD framework validated our process by helping the research team examine and discuss the issue in a variety of ways. The literature review, audience characterization, and needs analysis stages alone facilitated a triangulation of methods and were further reinforced by the above described methods incorporated throughout the process. Even though we did not reach the stage of formally implementing and evaluating interventions, the ILD framework encouraged participants to continuously reflect on previous stages of the process and to re-examine their findings and interpretations as they moved towards a more comprehensive understanding of the issue.

Democratic validity. This criterion helps to measure the level of collaboration with the people who have a stake in the problem under investigation (Herr & Anderson, 2005). Since this project took place in the context of WISET, stakeholders were those with an invested interest in the organization and their mission. However, even at such a localized level, the breadth of stakeholders can be diverse. Aside from staff and volunteers, WISEST stakeholders could

include program participants, parents, teachers, and professional and academic mentors involved in their programs. Our team consisted of two WISEST staff and two regular volunteers with STEM related careers, which may be viewed a limiting factor when assessing the democratic validity of our project. However, research team members brought a variety of perspectives to the table and collaborated effectively throughout the process.

Dialogic validity. According to Herr and Anderson (2005), dialogic validity is promoted by forms of peer review in PAR. They suggest doing this through critical consultation and dialogue with other action-based researchers or through PAR publishing venues. Being a master's capstone project, this criterion was partially addressed through the student-supervisor consultation that occurred throughout the process, but peer review did not occur at the level Herr and Anderson (2005) recommend. This validity criterion is a challenging one for me as a graduate student because I am new to PAR and have a limited network of peers to draw from in this area. However, I recognize the benefit dialogic validity offers PAR and recommend researchers consult their peers whenever possible to strengthen their projects.

Keeping the momentum in engaging more women in DSC

Overall, I believe the PAR goal of developing theoretically informed practice (McTaggart, 1994) is visibly evident in this project. Even without formally implementing interventions, the WISEST research team participated in the praxis of developing new ways of understanding and addressing the issue of women not engaging in DSC. The collaboration, empowerment, and self-reflection that are the cornerstones of PAR all contributed to the successful initial design of educational interventions.

WISEST's involvement in this project makes me confident that this work will contribute to helping women become more engaged in DSC. I feel involving individuals and outreach organizations with a shared vision and mission in PAR is key to ensuring action takes place, particularly when action is linked to educational outcomes. WISEST already has the benefit of having the drive and resources needed to implement educational programs but now they also have the knowledge they need to effect real change in the representation of women engaging in DSC.

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Appendix A

Invitation to Participate in a WISEST Research Project

Changing the digital landscape: a participatory action research project to increase the representation of women using digital science communication

WISEST is partnering with Kristy Burke, a graduate student in the Faculty of Extension's Masters of Arts in Communications and Technology program to explore how we can get more women involved in digital science communication.

As a person affiliated with WISEST or its UA-WiSE and Wiser networks, you are being invited to participate as one of our researchers in this participatory project. By participating, you will have the opportunity to work in a collaborative group to better understand the issues that contribute to fewer women engaging in digital science communication and play an active role in the development of real interventions designed to encourage more women in STEM to engage in digital science communication. Examining the issue at the localized level of WISEST can shed light on the broader issue and potentially help the overall issue of women being underrepresented in STEM.

Commitment

The WISEST research team is expected to meet beginning sometime in mid-April (exact date to be determined). The first meeting will include an **Orientation to Participatory Action Research**, to familiarize the team with the process, discuss roles, and to set project goals. How often and the length of the meetings depends on what the team agrees to (e.g. one all day meeting or four two-hour meetings, etc.) but is not expected to exceed a four-week commitment.

Kristy will facilitate the sessions to guide the team through the process, but participants should be prepared to conduct research and execute tasks that they assign at their meetings.

Benefits

Participatory action research involves a group of like minded people coming together to address a shared concern. By participating in this research project, you will have the opportunity to play an active role in the development of real interventions designed to encourage more women in STEM to engage in digital science communication. Examining the issue at the localized level of WISEST can also shed light on the broader issue. Furthermore, increasing the representation of women in STEM online can potentially help the overall issue of women being underrepresented in STEM.

This research will benefit WISEST and its networks by helping them to better understand their audiences' learning needs in digital science communication and assist in developing tangible intervention or educational strategies. It will benefit you, as a researcher, by increasing your own personal knowledge and understanding of the issue and by giving you the opportunity to incorporate your new knowledge into your own practices.

Appendix B

INFORMATION LETTER and CONSENT FORM

Study Title: Changing the digital landscape: a participatory action research project to increase the representation of women using digital science communication

Research Investigator:
Kristy Burke
University of Alberta
Edmonton, AB, T6G 2R3
kblurke@ualberta.ca
780-999-8604

Supervisor (if applicable):
Dr. Thomas Barker
University of Alberta, Faculty of Extension
Edmonton, AB, T6G 2R3
ttbarker@ualberta.ca
780-492-7651

Background

As a person affiliated with WISEST (Women in Scholarship, Engineering, Science, and Technology), you are being invited to participate in *Changing the digital landscape: a participatory action research project to increase the representation of women using digital science communication*. As a participant in this project, you will play an active role as a researcher on a research team. In other words, you help conduct the research. During the project, you will work in a collaborative group to better understand the issues that contribute to fewer women engaging in digital science communication by looking closely at WISEST's local community.

My role will be to facilitate the research process and to ensure a collaborative, respectful, and supportive environment.

The results of this research will be used to develop potential interventions or educational materials for WISEST and its networks, with the intent to increase their audiences' skills and capacity in digital science communication. They will also be used for the capping project I am completing for the Masters of Arts in Communications Technology program I am enrolled in at the University of Alberta's Faculty of Extension.

Purpose

The purpose of this research is to investigate how a WISEST research team can work collectively to develop a more critical understanding of why so few women engage in digital science communication and then use the knowledge generated by the group to the design educational materials or outreach interventions that encourage more women to get vocal about STEM online.

Study Procedures

Participants will attend a series of research team meetings designed to identify and define the problem of fewer women engaging in digital science communication but will examine the issue at the localized level of WISEST and its networks.

As a facilitator, I will guide the research team through research stages that involve characterizing our audience and conducting a needs analysis – both integral to identifying and understanding the issue we want to address. The participatory nature of this research means the research team will collectively determine the methods they will apply while navigating through each stage and analyze data to help develop potential educational materials or outreach interventions.

The first meeting will include an **Orientation to Participatory Action Research**, to familiarize the team with the process, discuss roles, and to set project goals. The number and length of meetings depends on the schedule set by the research team but are not expected to exceed more than one per week for a four to five-week period (if assuming 1-2 hour sessions, longer sessions would require fewer meetings).

Benefits

Participatory action research involves a group of like minded people coming together to address a shared concern. By participating in this research project, you will have the opportunity to play an active role in the development of real interventions designed to encourage more women in STEM to engage in digital science communication. Examining the issue at the localized level of WISEST can also shed light on the broader issue. Furthermore, increasing the representation of women in STEM online can potentially help the overall issue of women being underrepresented in STEM.

This research will benefit WISEST and its networks by helping them to better understand their audiences' learning needs in digital science communication and assist in developing tangible intervention or educational strategies. It will benefit you, as a researcher, by increasing your own personal knowledge and understanding of the issue and by giving you the opportunity to incorporate your new knowledge into your own practices.

There is no cost to conducting this study and there is no compensation for participating.

Risk

There are no foreseeable risks to you from participating in this study.

Voluntary Participation

You are under no obligation to participate in this project. Your participation is completely voluntary, and you will not be asked any specific questions to include as data because you are a researcher – not a research subject. You can opt out without penalty at any time.

Confidentiality & Anonymity

This research project is for a final capstone project for the University of Alberta's Faculty of Extension Masters of Arts in Communication Technologies program. It will also be used to provide WISEST with knowledge and resources about the issues impacting women's use of digital science communication and provide them with potential interventions or educational materials for their programs.

You will at no point be identified by name in my final capstone project report. Data collected by the research team will be kept by WISEST and shared with me as per a data sharing agreement. Any data shared with me will be anonymized. Though you will be anonymous in my final capstone project report, your role and relationship to WISEST might be identifying factors. I will do my best to maintain your anonymity in the final report.

Data are to be kept in a secure place for a minimum of 2 years following completion of the research project, and electronic data will be password protected until it is deleted. All research notes from the research team meetings will also be stored digitally in a password protected program. WISEST will maintain ownership over any data the group collects.

As a research team participant, you will be provided with a final copy of the final capstone report.

I do not have future plans for data shared with me beyond the scope of this project, but WISEST will retain ownership of the data and potentially use it for future program development.

Further Information

Researcher Contact:

Kristy Burke
klburke@ualberta.ca
780-999-8604

This research project did not require research ethics board approval as it is out of scope of their mandate.

Consent Statement

I have read this form and the research study has been explained to me. I have been given the opportunity to ask questions and my questions have been answered. If I have additional questions, I have been told whom to contact. I agree to participate in the research study described above and will receive a copy of this consent form. I will receive a copy of this consent form after I sign it.

_____ _____

Participant's Name (printed) and Signature Date

_____ _____

Name (printed) and Signature of Person Obtaining Consent Date

Appendix C: Characterization Checklist

Characterization Checklist		
Target Population	**What Is Known?** Summary	**Level of Confidence** 1 = low, 5 = high
1. Knowledge		
What level of knowledge do they have about the issue?		
What kind of understanding do they have of current events related to the issue?		
How familiar are they with terminology and concepts related to the issue?		
2. Skills & Abilities		
What kind of skills, experience, or prior training do they have related to the issue?		
3. Incentives		
What are the consequences of action or inaction (i.e., are they rewarded or penalized or does nothing happen)?		
4. Support		
What factors affect their ability to access, attend, or utilize training or tools or techniques?		
5. Motivation		
What level of value do they place on actions and decisions affecting the issue?		
Do they believe or expect that it is within their ability to take action or make meaningful decisions affecting the issue?		
What do they value that is linked to the issue (i.e., what are they most concerned about)?		
6. Opinions		
What attitudes and biases do they have about the issue?		
What are their perspectives about the problem, their relation to it, and its causes and solutions?		
7. Cultural Characteristics		
What are the distinct cultural factors that affect their actions and decisions, which in turn influence the issue?		

Appendix E: Data Analysis Exercise

Pillar	**Unhappy or unengaged digital science communicator (from survey results)**	**Interventions?** ----------> Complete this column last	**Happy or engaged digital science communicator (from our characterization and survey results)**
Motivation	Don't see the value for the time it takes - the majority do not make time Feel it is not necessary for their job or does not enhance their career (we did not identify this in our original assessment as a motivator) Have fear issues around privacy and personal identity Feel their work/area is not interesting Almost 50% said they don't follow any digital science communicators online Don't feel it's appropriate for professional use or it's not encouraged in their field	Create tools that make DSC easier - help people with minimal digital literacy make something Mini how-to guides for creating content/platform use Strategies to make women see the value (public comm/professional benefits)- have the conversation with them, use our own platforms more effectively, lead by example, connect them to role models Encourage use of professional vs private profile and educate about the risk Create resource or articles about digital privacy, online hostility Develop strategies to help women communicate the relevance of the area they work in Suggest digital science communicators to follow	Recognize the professional development, career enhancement, and networking opportunities Like engaging the public and reaching a wider audience Feel their work/area is interesting

Communication Skills	Lack of confidence Don't want negative feedback Feel men are seen as more credible	Teach women how to find credible resources and citations Educate women in developing a personal brand/style Teach women to "tell a story", using narrative to talk about science with digital media Teach women to communicate relevance and impact	Have confidence in communicating complex ideas Feel confident in having a personal style Want to develop a personal brand/voice
Scientific Knowledge	Have a fear of being misunderstood Don't' feel like an expert (may be more applicable to younger respondents)	Reinforce that women have time to do research and post thoughtful, scientifically sound information Conduct exercises in critical thinking Teach women the difference between reliable vs unreliable academic/online sources	Ofen use digital science content as a resource Feel confident as an expert (this may be more applicable to women more advanced in their career)
Digital Literacy	Don't follow other other digital science communicators Lack of training in digital platforms and therefore not confident Use digital platforms more for learning than to produce DSC	Encourage the use of a variety of platforms for digital science communication Provide examples across platforms to demonstrate diverse uses of digital media Challenge women to follow digital science communicators so they can see what others are doing	Support the online female science community Feel confident in their platform use Don't feel restricted to a limited number of platforms for digital science communication

		Offer training on digital platforms, clarify digital media vs social media Create weekly digital media challenges Create an online community where women could take turns writing or co-authoring posts, or have opportunities for mentorship - make it a community where women have trust and can overcome confidence issues Create a blog for students to post content using multi-modal digital media and invite female scientists to comment on posts	