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Foreseen Demands for Up-and-coming Science Communicators and Recommendations for Science Communication Training Programs

Abstract

Citizens interact with science on a daily basis, yet their understanding and opinions of scientific issues are formed with little scientific information. Science communication literature has called for scientists to take a more active role in engaging with the public through science communication efforts. However, scientists face demands and challenges that dissuade or prevent them from engaging in genuine communication efforts with a lay audience, including a lack of training. There has been an identified need for increased training programs for science communicators and students, but only a small number of programs currently exist. The purpose of this study was to identify demands faced by scientists who participate in communication practice in agricultural disciplines at Texas Tech University and to develop foundations for future science communications training curriculum at the college and/or university level. This descriptive, qualitative study consisted of semi-structured, in-depth interviews with 10 scientists at Texas Tech University who were identified as sought after for a variety of media interviews and communication efforts, and a criterion sampling strategy was used to identify "sought-after" communicators. The results of this study found that major demands faced by scientists include time constraints and academic value, and those demands inhibit genuine science communication efforts. Finally, recommendations regarding pedagogical foundations and subject matter content were developed for implementation in future science communication coursework at Texas Tech University.

Keywords

science communication, curriculum research framework, constructivism communication theory, higher education curriculum

Authors

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Introduction

According to the National Academy of Sciences (NAS), "people face an increasing need to integrate information from science with their personal values and other considerations as they make important life decisions" (NAS, 2017, p. 1). While the public is continually exposed to scientific information and asked to make decisions on general and agricultural science issues, their scientific literacy level is generally very low (Liu, 2009). Previous research shows the public's science illiteracy is due to scientists' failure to communicate effectively (Treise & Weigold, 2002) but more importantly, a lack of trained science communicators and journalists (Smol, 2018).

There are several factors that prevent a scientist from taking part in communication activities including lack of time (Fleming, 2009; McLeod-Morin et al., 2021), lack of training (Brownell et al., 2013), and fear of misrepresentation (McLeod-Morin et al., 2021; Peters et al., 2008). Fleming (2009) noted the average scientist, aside from having the expertise, rarely has enough time in their daily lives to dedicate to communication efforts. Sturzenegger-Varvayanis et al. (2008) discovered more than 80% of scientist respondents cited "time constraints" as a major reason for lack of communication efforts. In addition to time constraints, scientists "usually receive no explicit training in communication of scientific concepts to a layperson audience" though they are often highly skilled technically (Brownell et al., 2013, p. E6). McLeod-Morin et al. (2021) found that time, funding, and fear of misrepresentation were common challenges that limited communication and outreach with the public among interdisciplinary agricultural research center directors. A study exploring scientists' barriers for science communication found that 90% of respondents saw misrepresentation or misquoting of technical information, as a factor that dissuaded them from speaking with the public or media (Peters et al., 2008). Hunter (2016) stated that misinformation and public distrust in scientists, and in science in general, creates a barrier between scientists and the public. In a similar vein, the gap that exists between the scientist and the public leads scientists to shy away from attempting to engage in communication efforts (Fleming, 2009).

Citizens across the globe, particularly within the United States, vary in their understanding of science-related issues. For example, a study conducted in 2019 found science knowledge varied greatly based on topic and respondent education level (Kennedy & Hefferon, 2019). While concerns regarding public scientific literacy remain toward the forefront of the science community's minds, there are also concerns revolving around lack of science education in primary and secondary students, as well as the public's general acceptance of "pseudoscience" (Liu, 2009). In response, the science community has called upon its members to engage with the public to build trust and understanding of science. Ralph Cicerone, former president of NAS, stated that scientists must "do a better job of communicating to the public… [to] communicate the valuable role science plays in the world and to reinforce and enhance positive attitudes toward science" (2006, para. 4).

The call for scientists to act as communicators of scientific findings has been echoed throughout science communication literature (Greenwood & Riordan, 2001; Fleming, 2009; NAS, 2016; Leshner, 2003). Training up-and-coming scientists within their university studies to communicate effectively with the public has been suggested by both researchers and practitioners as a much-needed opportunity for skill development (Bankston & McDowell; Kuehne et al., 2014; Leshner, 2007; Rodgers et al., 2018). However, a lack of training programs for graduate students has been noted (Brownell et al., 2013; Bankston & McDowell, 2018;

Leeming, 2017; Wanner, 2015; Raoul Tan & Potocnik, 2006). Skills and pedagogy that would inform the development of science communication curriculum in higher education needs to be determined to educate and train the next generation of scientist communicators.

There have been a number of programs in the United States that focus on improving scientists' engagement with the public, including the American Association for the Advancement of Science's Center for Public Engagement and Stony Brook University's Alan Alda Center for Communicating Science, where facilitators develop programming for workshops that balance theoretical communications foundations with practical, improvisation-based skills applications (N. Leavey, Personal Communication, July 2020). These science communication training programs vary across the globe and are often divided between "media training" and "communication training" with different goals and teaching methodologies. Some groups supporting communication training programs focus their efforts more closely on one-way dissemination, rather than two-way dialogue and professionalism in science communicator-audience interactions (Baram-Tsabari & Lewenstein, 2017). Furthermore, training fails to prepare scientists for communication with non-expert audiences, beyond what can be taught during traditional graduate coursework or "discipline-specific seminars" (Clarkson et al., 2018). Despite the development of a small number of training programs to prepare scientists and students for science communication efforts, there have not been many attempts made to measure the effectiveness of these programs according to Clarkson et al. (2018).

Theoretical Framework

Constructivism communication theory and curriculum research framework (CRF) served as the theoretical frameworks to guide this study. Constructivism communication theory seeks to explain the differentiating factors between skilled and less skilled communicators (Delia, 1977). The theory states that skilled and effective communicators possess specific competencies that allow for the production of highly developed messages. As part of this message production process, skilled and effective communicators can implement a variety of communication strategies within their communicator "toolbelt," a repertoire that is developed based upon a mix of experience, social cognition, and interpersonal constructs (Applegate, 1982). By implementing constructivism communication theory, participants in this study were measured based on the competencies and skill sets outlined, which can be implemented in future communications training efforts.

Curriculum research framework (CRF) was developed by Clements (2007). CRF uses a research-based approach to develop curricula for a variety of educational settings and is composed of three major categories within the curriculum development model (Clements, 2007). These categories include A Priori Foundations—which will be the focus of this study—Learning Model, and Evaluation. Subject Matter Foundations and General Foundations, two phases within the A Priori Foundations, focus on describing the academic goals and specific subject matter to be incorporated into the curriculum (Clements, 2007).

By implementing CRF, the insights and recommendations provided by participants will contribute to the Subject Matter Foundations and General Foundation phases within the A Priori Foundations category of the curriculum development model. Recommendations regarding the structure and theoretical, or skills-based, foundations of a communications training program will contribute specifically to the General Foundations phase. Insights regarding the teaching of specific technical skills or competencies will contribute to the Subject Matter Foundations phase.

With the first phase of the CRF completed, further work can be done to develop and launch a full-scale communications training program.

Purpose and Objectives

The purpose of this study was to identify and describe perceived challenges faced by scientists who take part in communications and develop a set of recommendations regarding science communication training programs at the university level.

The following research objectives were developed to guide this study:

RO1: Describe the demands scientists foresee for up-and-coming science communicators.

RO2: Develop a set of recommendations that can be used to further develop science communication training programs at the university level.

Methods/Procedures

This study used semi-structured, qualitative interviews to collect detailed opinions and experiences of scientists who regularly take part in communication activities. Anderson (2010) notes that qualitative research has the unique ability to examine a specific issue in a more detailed fashion and provides experiential data that is more powerful and compelling than quantitative methodology. The target population of this study consisted of agricultural scientists who regularly communicate in various ways at Texas Tech University. A purposive sampling method was implemented to identify appropriate participants who could provide adequate information and insight regarding communication, challenges faced by scientists and recommendations on communications training opportunities. The following criteria were established, and participants had to meet two of the three criteria to be included in the study:

1. Faculty member or researcher at Texas Tech University in an agricultural field.
2. Participated in at least five media interviews or commentary segments within the last year (as of July 1, 2020) based on a Google News search.

-OR-

3. Participated in at least two speaking engagements (as a guest speaker/presenter) at a Texas agriculture industry conference or field day within the last year (as of July 1, 2020) based on a Google search.

A total of 10 participants were recruited for this study which meets recent studies on data saturation being achievable with a sample size of six to 12 participants (Guest et al., 2006). The 10 participants who were interviewed for this study were all scientists from a variety of disciplines within the college of agriculture at Texas Tech University. The gender distribution of participants was mostly males (n = 9). Participants' fields of research and teaching included animal science, meat science, agricultural economics, and horticulture; the majority were focused on plant and soil science (n = 4). All participants had a faculty appointment at Texas Tech University that included elements of teaching and research, and roughly half had some type of extension role in addition to teaching responsibilities.

It should be noted the majority denied having any formal training in communications or media relations, with formal training referring to coursework or self-selected short courses. A small number (n = 2, 20%) of participants stated they had attended a workshop or professional development event related to communications and/or media relations. However, the remainder of participants described their development of communications skills as being self-taught or learned with on-the-job experience. Table 1 summarizes the academic field and characteristics of each participant.

Table 1
Description of Participants (N = 10)

Identifier	Academic Field of Work	Gender
Participant One	Meat Scientist	Female
Participant Two	Meat Scientist	Male
Participant Three	Agricultural Economist	Male
Participant Four	Animal Scientist	Male
Participant Five	Animal Scientist	Male
Participant Six	Plant Scientist	Male
Participant Seven	Plant Scientist	Male
Participant Eight	Plant Scientist	Male
Participant Nine	Plant Scientist	Male
Participant Ten	Plant Scientist	Male

Data collection occurred through standard procedure approved by the university's Institutional Review Board. Ary et al. (2009) stated the human researcher is the "primary instrument" for collecting and analyzing qualitative interview data, one that is flexible and responsive enough to capture every bit of context and information. Therefore, interviews are most appropriate in qualitative research to gather insight and anecdotes from participants.

A researcher-developed guide was created to guide the semi-structured interviews conducted in this study. Factors influencing effective communication, science communication, and recommendations on communication training programs examined in previous literature were incorporated to develop the open-ended questions for each interview session. Open-ended questions are used in interviews to explore topics, understand phenomena, and gather rich information that can be used in the development of theory (Weller et al., 2018).

Participants were asked to give an overview on their role as a scientist who communicates in an agricultural field, including the various methods through which they communicate to scientific and lay audiences. Then, participants were asked to describe the characteristics and competencies possessed by sought-after communicators in science fields; after providing a description of the traits exhibited by perceived successful communicators, participants were asked to self-identify characteristics and competencies they felt made themselves effective science communicators in their given fields. Participants were also asked to provide insight into their experiences and training as it related to both media relations and engagement with lay audiences, their thoughts on the development of science communication programming at the university level, and their overall experiences in their communications efforts. The final portion of each interview asked participants to provide insight on the argument that science communication to the public is a civic responsibility of the scientific community.

Once participation in the study was confirmed, interviews were scheduled and conducted through Zoom or Skype during the summer of 2020. Each interview lasted approximately 45 to 60 minutes. Interviews were conducted in a virtual space due to the COVID-19 pandemic. Participants were asked to verbally consent to participate in the interview and granted permission for the interview to be recorded for transcription purposes. After consent was received, the interview began.

Prior to analyzing data, each participant was assigned a numerical indicator (1-10) to ensure anonymity to the participant. After preparing transcriptions using the Otter software and cross-checking against audio recordings, NVivo data management software was used to assist with data analysis and management. NVivo served as a vehicle for data storage and organization while the lead researcher analyzed the interview data for themes and meaning.

Data were analyzed using an inductive method. Inductive analysis is when the researcher attempts to derive meaning and sense from participants' interview transcripts (Welsh, 2002). Chandra and Shang (2019) state that inductive analysis allows for the examination of themes or topics that emerge repeatedly in the data. Inductive analysis involves the close reading of textual data and the development of code categories based on repetitive information segments found within said data (Thomas, 2003).

Guba and Lincoln (1989) posit that research needs to satisfy four criteria to ensure trustworthiness and research rigor in qualitative analysis: credibility, transferability, dependability, and confirmability. Credibility was established through triangulation, researcher reflexivity and the development of a coding system. We achieved transferability through the implementation of a purposive sampling strategy, which allowed for the selection of appropriate individuals that could provide information related to the research objectives. Additionally, rich, thick descriptions were implemented during data collection and analysis to help the reader better understand the phenomenon being investigated. This study's methodology was carefully and meticulously documented to ensure dependability of the procedures, and an audit trail was kept. Data collected for this audit trail included raw interview transcriptions, field notes, data analysis notes, criterion for participant selection, IRB approvals, interview guide, and other relevant information. Confirmability was achieved through the lead researcher's subjectivity statement, outlined below.

Since the researcher is the instrument, mistakes can be made, and personal biases can interfere (Merriam, 1998). The lead researcher conducted the interviews. She grew up on a family farm in Missouri and was previously employed by an agricultural laboratory for two years. While these experiences may have influenced the interpretations of this data, the lead researcher's primary role was simply to allow the participants to speak about their perceptions of science communication effectiveness, and to identify themes in the data that could lead to the insightful development of recommendations for science communication training at Texas Tech University.

Results/Findings

This study sought to discover perceived challenges faced by scientists who take part in communications and develop a set of recommendations for future science communication training curriculum at the university level.

Research Objective One

Research Objective One sought to describe demands faced by scientists who participate in communications efforts and challenges they see for up-and-coming leaders in scientist-led communication. From a general standpoint, the perceived challenges revolved around potential misrepresentation, lack of time, and devaluation of communication efforts. Three themes emerged from the data to describe long standing challenges faced by scientists: Online Media, Time Constraints, and Academic Value.

Online Media

Online media, particularly news websites and social media platforms, were identified by nearly all participants as challenges to science communication. These platforms were identified as challenges for scientist-led communication because social media allows the public to rapidly access and spread misinformation regarding science. Participant one (meat scientist) described the challenge of online media platforms being an opportunity for individuals to spread and access misinformation regarding scientific issues. They stated:

> I think one of the biggest problems with communicating as a scientist is the web. People can go on the internet and find out whatever information they want and you can find just as many stories to support what your science is as you can to refute what your science is. (Participant One, meat scientist).

Participant seven (plant scientist) outlined the challenge of attempting to counteract pseudo-science while promoting “good science” and the impact these efforts have on the role of a science communicator:

> Another big one is all the pseudoscience and all the poor information that's out there right now. I think we spend as much time as science communicators refuting bad science as we do promoting good science, or new technologies and new research, because the internet and social media, for all of its great qualities, unfortunately, is a breeding ground for bad science communication (Participant Seven, plant scientist).

Time Constraints

Participants, who balanced faculty appointments with a variety of responsibilities such as extension and research responsibilities, named time as a longstanding challenge for science communication efforts now and in the future. For one participant, this meant struggling to balance time away from the research lab and faculty requirements with communication:

> How can we commit more time to make communication efforts? One of the problems with have with the transgenic issue is that I can go and do interviews, go to Congress, or go to a conference once a month, once every two months, because I have to work. But there are people on the other side of the issue who are working every day to transmit the opposite viewpoint (Participant Nine, plant scientist).

These time constraints were viewed as a challenge that will continue to exist for scientist-led communications, especially those who are in academia, without a real solution. One participant stated the lack of time not only limited communication efforts, but also affected their ability to stay abreast of technology development and new information in their field of study:

> I have earbuds and I return a lot of phone calls when I'm driving just simply because of the time limitation that I frequently face. And, you know, there's just so many new topics to keep up with too, and there's never enough time (Participant Eight, plant scientist).

Academic Value

The theme of academic value was described by participants as a devaluation of their non-academic communications efforts as compared to traditional efforts such as research publication or invitations to speak at academic conferences. Participant 10 (plant scientist) noted their public outreach efforts had been downplayed by superiors in favor of activities that would aid in gaining faculty tenure. This devaluation or bias toward non-traditional communication efforts is one of implied nature, as participant three (agricultural economist) explained:

> You'll never hear an administrator say you shouldn't do that. But what they'll always say is, "well, we want more of these, we want more of these, we want more of these." And so, the valuation of the others [communication efforts] tends to be diminished (Participant Three, agricultural economist).

Similarly, one participant's experience with devaluation of their science communication efforts came through administration nonchalance. Participant five recounted:

> I view them [science communication efforts] as outside of my job or career because they don't seem to be a part of it… If I had spoken at different industry conferences, but because of that I had two less publications, I feel like the response would be "why do you have two fewer publications" or "why are you not meeting your publication requirements?" (Participant Five, animal scientist).

Interestingly, participant seven implied that although pressure is placed by academic institutions, some portion of this perceived challenge comes from the scientist themselves. This participant said:

> I think it's the concept that they're handing you're like, "Oh, no, I need to be spending my time trying to get more citations instead of getting my information in people's ears" right? And I understand that, I understand why. But it can absolutely be a challenge (Participant Seven, plant scientist).

Research Objective Two

Research Objective Two sought to develop recommendations for science communication training curriculum at Texas Tech University. Participants were probed for their insight into pedagogy and suggested competencies for this curriculum to focus. Participants were also asked to provide their thoughts on the civic responsibility placed upon scientists to communicate their work to the public. Three themes regarding specific competencies for this curriculum emerged from participant interviews: Presentations, Online Media, and Message Distillation.

Need for Communications Training Programs

Support for a graduate communications training program was echoed among all interview participants. All participants identified a need for the availability of communications training for graduate level students at Texas Tech University. Participant three admitted that a lack of adequate training exists in current graduate curricula, and stated:

> We do a terrible job in graduate programs of two things. One of them is teaching people how to communicate in anything outside of academic settings. And two, we do a terrible job of teaching them how to teach. So, they come out of grad school being really good researchers. They know how to do research. But they don't know how to then break that down into say, an informational bulletin, or a news media summary, or even a Twitter post or something like that. So, I think one of the things that we need to consider in graduate programs is some sort of training in communication (Participant Three, agricultural economics scientist).

In addition to the identified need for future scientists, participants noted that communications training programs benefit students who may find a career beyond typical bench science. Graduate students who pursue a career in the agriculture industry could use the same skill and competency development as those who remain in an academic setting. To this effect, participant four said:

> Regardless of where you go, you're trying to sell ideas or sell yourself, basically. So, whether you're trying to sell an idea to the media, or you're writing a grant and selling it to sponsor to the funding agency, or you go into a private company, and there's five ideas going forward to the CEO, and he only has the funds to select one or two of them, right? You've got to work out how to effectively communicate what you're trying to do succinctly, effectively and in a very compelling way (Participant Four, animal scientist).

Breakdown of Program Foundation

By and large, participants agreed that the basis of any communications training coursework should have a greater weight placed on skill development, rather than communication theory. Participant nine (plant scientist) said "I think a brief introduction about communication principles and theories would be nice, but it should be mainly a technical skill-based course." Although most felt that both theoretical and technical components had their merit in a training program, participant three stated:

> I think theories are good, but I don't know that they're great in trying to teach somebody to be a great communicator, you know. But they do need to understand something about how the brain thinks, how people hear and understand things. But you don't need a course on that because they're not these people are not going to be doing research and communication. They don't need to know theories to test. What they need to know is 'how do I do this?' And so, I think some introduction to the theory is fine, but it probably needs to be a lot more sort of technical skills-based and experience based (Participant Three, agricultural economics scientist).

In a similar vein, participant seven (plant scientist) made the point that a theoretical component provides context to the skills being taught: "I think context is always important. And so, if we tell someone, this is how you should approach this type of interview, maybe having a little bit of context of why is very important."

Skills and Competencies to Teach

Participant three (agricultural economics scientist) mentioned skills and experience when describing their ideal breakdown of a scientist-oriented communications training program. This sentiment resonated in nearly all interviews with this study's participants, that curriculum should involve technical skill development and experiential learning opportunities for students. From the interview data, themes emerged regarding specific skills that should be the focus of training efforts. These skills were Presentations, Online Media, and Message Distillation.

Presentations

Mastering the ability to give a presentation, with or without the use of visual aids, to a lay audience was noted as an important topic to be taught in a graduate communication training program. Participant nine stated:

> So, you'll show them an example of a guy giving a presentation, how he moves in the stage, how he uses his hands, how he modulates his voice, and what to say what not to say. And conversely, you'll show them an example of someone that is doing everything wrong. (Participant Nine, plant scientist).

Online Media

Training students to effectively share their science using online media, including social media platforms, was mentioned as a skill that should be incorporated into science communication training curriculum. This skill was noted to be particularly important because of the usefulness to students regardless of their intended career path and eventual science communication opportunities. Participant seven suggested a general approach to presenting this skill for instruction:

> I think we need to be prepared to [talk to traditional media outlets], but maybe if we are focusing more on how to have a good social media presence or a good non-traditional media presence, because that's something we're all doing, and how to more effectively address our science through the social media stuff they're already doing. Maybe that's a good area, focus going forward, and then maybe have a couple of specialized kind of things about actual media training for students that think that's going to be in their future (Participant Seven, plant scientist).

Message Distillation

Participant four (animal scientist) explained one aspect of message distillation, audience awareness and adaptability: "I think one thing that people should have as awareness as well, awareness of what you're trying to communicate and what people are hearing. To make sure that what you want to communicate as what people hear."

Discussion/Conclusions/Recommendations

This study sought to identify and describe perceived challenges faced by communicators and develop a set of recommendations for future science communication training curriculum at the university level. The perceived challenges revolved around potential misrepresentation, lack of time, and devaluation of communication efforts. Three themes emerged from the data to describe longstanding challenges faced by scientists: Online Media, Time Constraints, and Academic Value.

The ability for misinformation to be rapidly accessible and spreadable was the basis for participants' determination of online media platforms to be a challenge and potential barrier for science communication. Previous research corroborates this perceived challenge of potential misinformation or misrepresentation to effective science communication (Fleming, 2009; Hunter, 2016; McLeod-Morin et al., 2021; Peters et al., 2008). Participants also noted that time constraints affected their ability to engage in communication efforts as well as their ability to stay up to date with new technologies and research in their field of study. This was also found by Fleming (2009) who found that the average scientist does not have the time for genuine communication efforts and McLeod-Morin (2021) who found that agricultural research center directors did not have the time to devote to communication efforts. Sturzenegger-Varvayanis et al. (2008) found that most scientists name time constraints as a perceived reason for lack of science communication efforts. Participants noted that the devaluation or bias of science communication was of implicit nature and sometimes appeared in the form of nonchalance or underplaying efforts, primarily by administration or supervisors. Although participants stated superiors as the source of this devaluation, one participant noted that some scientists face this challenge due to internal conflicts and self-perceived pressure. This has been documented in previous research from Moore (2020) who found that extension specialists' communications efforts were downplayed by superiors. This also aligns with findings of McLeod-Morin et al. (2021) in that science communication efforts were not beneficial to the tenure and promotion process, thus not seen as a priority.

Overwhelming support for a training program was echoed among participants, and all stated the need for communications training at the graduate level. Participants stated the foundation of this curriculum should have a greater emphasis on skill development and experiential learning opportunities while still incorporating basic communication theories and principles. To these participants, experiential learning opportunities allow students to practice applying learned skills in realistic scenarios and receive constructive feedback for continual skill development. These findings align with previous research suggesting that curricula balance theoretical background and practical application of learned skills (Longecker & Gondwe, 2014; Brownell et al., 2013). It was interesting to find that participant responses were nearly verbatim in some cases, and this shows that science communicators feel strongly about specific program foundations and elements of pedagogy.

Participants varied in their opinion on the extent to which scientist-led communication efforts should occur, most participants agreed that having some entity acting as a communication vehicle and bringing science to the public was an obligation bore by the scientific community.

Three themes emerged regarding specific competencies for science communicators: Presentations, Online Media, and Message Distillation.

Having the ability to speak to a variety of audiences, with and without the assistance of visual aids, should be mastered by future science communicators. Additionally, providing an opportunity for students to give multiple presentations with multiple opportunities for feedback was of importance to scientists as stated previously. Research from Longecker and Gondwe (2014) suggests that this style of experiential learning is beneficial for students to gain understanding of the practical application of a communications principle. Having an understanding and mastery of online media communication was deemed important because of the continual shift toward online communication and applicability for a large variety of science communicators. It was intriguing to find that although many participants rated their comfort level with online media communication practically nonexistent, they called for a focus on this area. The inclusion of online media as an important competency for training programming shows that although the current generation of science communicators exhibits limited comfort regarding online media communications, they understand the importance and value of being able to confidently and effectively communicate science through online media (Darzentas et al., 2007). Finally, participants felt it was important to focus efforts on teaching students how to effectively distill their scientific message and read their audience to deliver an adaptable, digestible, and fluid message. This aligns with findings from O'Connell et al. (2020) who state that audience awareness, empathy, and building a connection with audiences are important skills in a communication training program. Similarly, science communication training facilitators have noted that previous training efforts have lacked elements of humanity and connection (Wapner, 2017). Previous research from Bray et al. (2012) suggests a focus on audience awareness and needs, as well as storytelling skills, in communication training efforts. Delia (1977) suggested that effective communicators implemented sophisticated communication strategies for the delivery of person-centered messages, and scientists' recommendation for the inclusion of these sophisticated communication strategies suggest that respondents are effective communicators. Furthermore, these findings suggest that scientists are cognizant of those effective communication strategies and of the importance of person-centered messages.

Based on the insight and suggestions presented by study participants, paired with previous literature regarding science communication training programs, a set of recommendations will be presented for the development of a science communication curriculum that can be implemented at Texas Tech University that is adaptable to other institutions. The development of these curriculum recommendations follows the A Priori Foundations as part of CRF (Clements, 2007). Participants contributed to the two phases within A Priori Foundations—General Foundations and Subject Matter Foundations. Those recommendations which fell into the General Foundations phase regarded the structure and theoretical foundations of a graduate science communication training program. Participants in this study noted that students would need incentivization for consistent and engaged participation in such a program, as these students are also juggling coursework and research responsibilities. In addition, regular class meeting times would allow adequate time for competency teaching and practice without overwhelming participants. Offering this training program as a for-credit course would incentivize participation in all course meeting sessions and could lead to opportunities for the development of a certificate program or minor in science communication. Participants also suggested that science communication curriculum contain elements of both theory and practice, with a greater focus on the practical application of learned skills. The inclusion of experiential learning opportunities will ensure that students are able to practice using the skills being taught within the communication curriculum and can do so in a real-world setting. Furthermore, experiential opportunities will allow for further refinement of skills as students receive feedback upon completion of practice activities. A science communication curriculum that balances theoretical communications foundations with practical, improvisation-based skills applications is similar to American Association for the Advancement of Science's Center for Public Engagement and Stony Brook University's Alan Alda Center for Communicating Science (N. Leavey, Personal Communication, July 2020).

It is therefore recommended that science communication training curriculum be broken into two levels, one being a brief overview of the topic or skill being studied and the other being an experiential opportunity for the practice and refinement of the skill of focus. Curriculum should include a brief theoretical foundation with a greater portion of instruction focusing on practical application of the competency of focus. While other subject areas such as media relations may be of interest to participants or practitioners, these opportunities should be offered as self-selected sessions unless otherwise founded by additional research as part of the CRF. There should also be a subsequent evaluation of program effectiveness.

Those recommendations that regarded the specific technical skills that should be taught in this program fell under the Subject Matter Foundations phase of CRF. Of the skills and competencies recommended, message distillation, online media, and presentations were of particular importance to the participants. These skills and competencies align with the sophisticated communications strategies implemented by effective communicators to deliver person-centered messages (Delia, 1977). Presentation skills, including best practices for a variety of presentation software, should be incorporated into programming. Familiarizing students with tools and presentation aids, in addition to teaching them about effective presentation techniques, will aid them in communicating effectively to a variety of lay audiences in a range of settings. Informing students of online media platforms and showing them how to establish and maintain a presence on them will ensure that findings and research can be communicated to the public across multiple mediums.

Limitations of this study include the lack of diversity in background and gender of participants. This study is also limited to scientists at one university who participate in communication practice. Future research should investigate the self-described competencies of sought-after science communicators in other scientific disciplines. Additionally, participants in future research should encompass a wider variety of individuals and scientists who are considered science communicators, including scientists in industry roles and those conducting research for organizations outside of a university setting. Expanding these research efforts into qualitative and mixed-methods analysis could yield additional insight into the characteristics and behaviors of effective science communicators. How to alleviate the pressures of the barriers for scientist-led communication efforts is a challenge within itself. Future research should seek to identify solutions to these barriers. Further research should investigate and evaluate effective communication techniques and competencies from the audience perspective. Understanding the skills, competencies, and characteristics for science communication that resonate with a lay audience will provide additional insight into effective communication techniques and will solidify previous literature suggesting the implementation of specific communication techniques.

References

Anderson, C. (2010). Presenting and Evaluating Qualitative Research. *American Journal of Pharmaceutical Education, 74*(8). https://doi.org/10.5688/aj7408141

Applegate, J. L. (1982). The impact of construct system development on communication and impression formation in persuasive contexts. *Communication Monographs, 49*(4). 277-289. https://doi.org/10.1080/03637758209376090

Ary, D., Sorensen, C., Razavieh, A., Sorensen, C. K., & Jacobs, L. C. (2009). *Introduction to Research in Education.* United States: Cengage Learning.

Bankston, A., & McDowell, G. S. (2018). Changing the Culture of Science Communication Training for Junior Scientists. Journal of Microbiology & Biology Education, 19(1). https://doi.org/10.1128/jmbe.v19i1.1413

Baram-Tsabari, A., & Lewenstein, B. V. (2017). Preparing Scientists to Be Science Communicators. Preparing Informal Science Educators. 437–471. https://doi.org/10.1007/978-3-319-50398-1_22

Bray, B., France, B., & Gilbert, J. K. (2012). Identifying the Essential Elements of Effective Science Communication: What do the experts say? *International Journal of Science Education, Part B, 2*(1), 23–41. https://doi.org/10.1080/21548455.2011.611627

Brownell, S. E., Price, J. V., & Steinman, L. (2013). Science Communication to the General Public: Why We Need to Teach Undergraduate and Graduate Students this Skill as Part of Their Formal Scientific Training. *Journal of undergraduate neuroscience education: JUNE: a publication of FUN, Faculty for Undergraduate Neuroscience*, *12*(1), E6–E10.

Chandra, Y., & Shang, L. (2019). *Qualitative Research Using R: A Systematic Approach.* Springer Publications.

Cicerone, R. J. (2006). Celebrating and rethinking science communication. *InFocus*, *6*(3). http://www.infocusmagazine.org/6.3/president.html

Clarkson, M. D., Houghton, J., Chen, W., & Rohde, J. (2018). Speaking about science: a student led training program improves graduate students' skills in public communication. *Journal of Science Communication, 17*(2), A05. https://doi.org/10.22323/2.17020205

Clements, D. H. (2007). Curriculum Research: Toward A Framework for "Research Based Curricula". *Journal for Research in Mathematics Education, 38*(1). 35-70. https://doi.org/10.2307/30034927

Communicators. *Preparing Informal Science Educators*. 437–471. https://doi.org/10.1007/978-3-319-50398-1_22

Delia, J. G. (1977). Constructivism and the Study of Human Communication. *Quarterly Journal of Speech, 63*(1). 66-83. https://doi.org/10.1080/00335637709383368

Effective Science Communication: What do the experts say? *International Journal of Science Education, Part B, 2*(1), 23–41. https://doi.org/10.1080/21548455.2011.611627

Fleming, J. S. (2009). Talking with Barmaids: The Importance of Science Communication in Today's Changing World. *The International Journal of Science in Society, 1*(1): 31-38. doi:10.18848/1836-6236/CGP/v01i01/51216

Greenwood, M. R. C., & Riordan, D. G. (2001). Civic Scientist/Civic Duty. *Science Communication*, *23*(1), 28–40. https://doi.org/10.1177/1075547001023001003

Guba, E. G., & Lincoln, Y. S. (1989). *Fourth Generation Evaluation*. SAGE Publications.

Guest, G., Bunce, A., & Johnson, L. (2006). How many interviews are enough?: An experiment with data saturation and variability. *Field Methods, 18*(1). 59-82. https://doi.org/10.1177/1525822X05279903

Hunter, P. (2016). The communications gap between scientists and public. *EMBO rep, 17*. 1513 1515. https://doi.org/10.15252/embr.201643379

Kennedy, B., & Hefferon, M. (2019). *What Americans know about science*. Pew Research Center. Retrieved from https://www.pewresearch.org/science/2019/03/28/what-americans-know-about-science/

Kuehne, L. M., Twardochleb, L. A., Fritschie, K. J., Mims, M. C., Lawrence, D. J., Gibson, P. P., Stewart-Koster, B., & Olden, J. D. (2014). Practical science communication strategies for graduate students. *Conservation Biology*, *28*(5). 1225-1235. https://doi.org/10.1111/cobi.12305

Leeming, J. (2017, April 14). The next generation of science outreach. *Naturejobs*. http://blogs.nature.com/naturejobs/2017/04/14/the-next-generation-of-science-outreach/#more-13381

Leshner, A. I. (2003). Public engagement with science. *Science, 299*(5609), 997. https://doi.org/10.1126/science.299.5609.977

Liu, X. (2009). Beyond science literacy: Science and the public. *International Journal of Environmental & Science Education*, *4*(3), 301-311.

Longnecker, N., & Gondwe, M. (2014). Graduate degree programmes in science communication: Educating and training science communicators to work with communities. In L. Tan Wee Hin and R. Subramaniam (Eds.), *Communicating science to the public* (pp. 141-160). Springer. https://doi.org/10.1007/978-94-017-9097-0_9.

McLeod-Morin, A., Rumble, J.N., & Telg, R.W. (2021). Challenges and motivations of science communication: An administrative perspective at land-grant universities. *Journal of Applied Communications*, *105*(3). https://doi.org/10.4148/1051-0834.2387

Merriam, S., & Tisdell, E. (2016). *Qualitative research: A guide to design and implementation* (Fourth ed., The Jossey-Bass higher and adult education series). Jossey-Bass, a Wiley Brand.

National Academies of Sciences, Engineering, and Medicine. (2016). *Science literacy: Concepts, contexts, and consequences*. National Academies Press.

National Academies of Sciences, Engineering, & Medicine. (2017). *Communicating science effectively: A research agenda.* The National Academies Press.. https://doi.org/10.17226/23674

Peters, H., Brossard, D., De Cheveigné, S., Dunwoody, S., Kallfass, M., Miller, S., & Tsuchida, S. (2008). Interactions with the mass media. *Science, 321*(5886). 204-205. http://www.jstor.org.lib-e2.lib.ttu.edu/stable/20054464

Raoul Tan, T. L., & Potocnik, D. (2006). Are you experienced? Junior scientists should make the most of opportunities to develop skills outside the laboratory. *EMBO reports*, *7*(10). 961-964. https://doi.org/10.1038/sj.embor.7400811

Rodgers, S., Wang, Z., Maras, M. A., Burgoyne, S., Balakrishnan, B., Stemmle, J., & Schultz, J. C. (2018). Decoding science: Development and evaluation of a science communication training program using a triangulated framework. *Science Communication, 40*(1). 3–32. https://doi.org/10.1177/1075547017747285

Smol, J.P. (2018). A crisis in science literacy and communication: Does reluctance to engage the public make academic scientists complicit? *FACETS, 3*. 952–957. https://doi.org/10.1139/facets-2018-0022

Struzenegger-Varvayanis, S., Eosco, G., Ball, S., Lee, K., Halpem, M., & Lewenstein, B. (2008). How university scientists view science communication to the public. In *Proceedings de la conférence PCST-10, Malmõ* (pp. 25-27).

Thomas, D. R.. (2006). A General Inductive Approach for Analyzing Qualitative Evaluation Data. *American Journal of Evaluation*, *27*(2), 237–246. https://doi.org/10.1177/1098214005283748

Treise, D., & Weigold, M. F. (2002). Advancing science communication: A survey of science communicators. *Science Communication*, *23*(3), 310–322. https://doi.org/10.1177/107554700202300306

Wanner, M. (2015, September 23). Training the whole scientist. *The Jackson Laboratory*. https://www.jax.org/news-and-insights/2015/september/training-the-whole-scientist#

Wapner, J. (2017, June 1). The Secret to Good Communication? Alan Alda Shares His Wisdom on Relationships and Science. *Newsweek*. https://www.newsweek.com/secrets-good-communication-alan-alda-relationships-science-618394

Weller, S. C., Vickers, B., Bernard, H. R., Blackburn, A. M., Borgatti, S., Gravlee, C. C., & Johnson, J. C.. (2018). Open-ended interview questions and saturation. *PLOS ONE*, *13*(6), e0198606. https://doi.org/10.1371/journal.pone.0198606

Welsh, E. (2002). Dealing with Data: Using NVivo in the Qualitative Data Analysis Process. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *3*(2). https://doi.org/10.17169/fqs-3.2.865