Introduction

Science literacy has been a difficult term to accurately define, although many scholars have attempted to do so. Essential components of science literacy are knowledge, competencies, context, and aptitude to apply these components to real-world experiences (Bybee, McCrae, & Laurie, 2009). Science achievement in the United States has been below average when compared to other countries (Bybee et al., 2009; Sapp, 1992). Bybee, McCrae, and Laurie (2009) evaluated science literacy using four components: scientific contexts, scientific competencies, scientific knowledge, and attitudes toward science. Scientific contexts include common occurrences that citizens encounter involving science and technology, such as health or the environment (Bybee et al., 2009). Scientific competencies include the ability to identify scientific problems and utilize scientific information (Bybee et al., 2009). Scientific knowledge includes understanding scientific concepts, such as earth and space and physical systems (Bybee et al., 2009). Attitudes toward science include an individual's enthusiasm for science (Bybee et al., 2009). Attitudes toward science are typically associated with an individual's awareness of science, and can lead to an individual's understanding of science (Burns, O'Connor, & Stocklmayer, 2003).

Agricultural literacy is a specific subset of science literacy referring to the non-farming public's knowledge of agriculture (Mercier, 2015). An agriculturally literate person is someone who "would understand the food and fiber system and this would include its history and its current economic, social and environmental significance to all Americans" (National Research Council, 1988, p. 8). The American public lacks agricultural literacy and science engagement, which could cause serious implications, such as uninformed voting on policies that will guide the future of the agricultural industry (Duncan & Broyles, 2006; Miller, 2004; Olper & Swinnen, 2013).

Low science and agricultural literacy can be addressed with effective science communication. Burns, O'Connor, and Stocklmayer (2003) defined science communication as using a combination of communication practices to create "awareness, enjoyment, interest, opinion-forming, and understanding" of science (p. 183). The goal of science communication varies depending on the communicator and the targeted audience. However, science communication typically includes sharing scientific findings, expanding the appreciation of science when understanding the world, increasing the knowledge or understanding of a particular topic related to science, influencing the opinions, behavior or policy preferences of the public, and seeking solutions issues that impact society (National Academies of Sciences, Engineering, and Medicine, 2017).

New inventions and discoveries that could greatly impact society have often gone unused because their benefits have not been communicated well to the public or because of the public's lack of trust in science (Hulcr, 2016). Hulcr (2016) noted that communicating about science is no longer optional, but necessary for the good of the public. When the public is more informed about science, it can make more informed decisions about important issues, such as public policy (Treise & Weigold, 2002). An informed public can also decipher among debates on ecological, economical, and social issues (Treise & Weigold, 2002). Publics that are informed about science and scientific issues can help individuals make more informed choices in their personal lives, including decisions related to personal health and agriculture (Nelkin, 1995). A clear need for effective science communication has been illustrated through the public's lack of understanding of science and weak science literacy (Hartz & Chappell, 1997; Paisley, 1998). Science communication must engage citizens in a way that will lead to a more knowledgeable society about science issues and topics (Dijkstra & Gutteling, 2012; Kleinman & Powell, 2010).

Emerging, but unaccepted technologies, such as genetic modification and water conservation behaviors, in the agricultural industry have illustrated a clear need for communication between scientists and agriculturists (Clarke, 2003). Farmers or agriculturists usually receive information from agricultural publications or company sales representatives, but little opportunity has existed for scientists without Extension appointments to communicate with agriculturists (Clarke, 2003). The agricultural industry is innovative and constantly changing, which means there is always new information to report and discuss. Communicators must help make information accessible to the public to keep farmers and agriculturalists informed and ensure the public is aware of advances that impact their daily lives (Ezezika & Mabeya, 2014). Communicating about agricultural science also impacts public trust and willingness to adopt new practices or technologies (Ezezika & Mabeya, 2014).

Examining agricultural science issues typically require diverse resources and interdisciplinary approaches because of the multidimensional outcomes related to the science (Corbett, Costa, Balas, Burke, Feroli, & Daratha, 2013). Diverse scientists from various disciplines will collaborate using different methods and research designs to more effectively approach scientific questions (Corbett et al., 2013). When scientists collaborate in a formal structure at a university, interdisciplinary centers are formed. Interdisciplinary centers in the United States have been categorized by three determinants: centers that encourage researchers to analyze problems in one discipline with methods used in another discipline, centers with diverse scholars working collaboratively on problems from their own discipline, and scholars chosen to work with the center based on the problem of interest and the expertise of the scholars (Alpert, 1969). Land-grant institutions have established interdisciplinary agricultural research centers to address complex science issues affecting the agricultural industry. The perceptions and beliefs of science communication reported by the interdisciplinary agricultural research center directors should be analyzed to determine what role these centers may have in communicating about agricultural science.

Literature Review

Communicating science is intended to inform or excite people about a topic that is often misunderstood and difficult to comprehend (Burns et al., 2003). The National Academies of Science, Engineering, and Medicine (2016) identified goals of communicating science, including excite others about science, help people appreciate science, increase knowledge, and affect people's opinions and perceptions. When scientists and communicators engage with the public about science and science-related issues, the public's opinions can be considered and included as change is enacted (National Academies of Science, Engineering, and Medicine, 2016). Through these goals, the general public is often given priority in the communication process. However, another important audience in science communication is the decision-makers (National Academies of Science, Engineering, and Medicine, 2016). Policy and science often influence each other, but according to the National Academies of Science, Engineering, and Medicine (2016), there is little evidence on how science communication influences policy decisions. It is important that communicators of science have a healthy working relationship with policy makers for several reasons, including allowing policy makers to use science and research to complement their decisions, develop science understanding among decision-makers, and for scientists and communicators to learn more about the needs of the general public and how science relates to those needs (National Academies of Science, Engineering, and Medicine, 2016).

Historically, science journalists have been charged with communicating science and research findings to the public. However, these journalists have often faced issues such as

difficulties working with scientists, lack of understanding of scientific reports, and a lack of resources provided by the news organization for whom they are reporting (Hartz & Chappell, 1997; Treise & Weigold, 2002). Treise and Weigold (2002) surveyed science writers, science news editors, and science communication scholars to identify opportunities and issues related to science communication and found these individuals were concerned about the process of learning about science, communication ethics, how technology is transforming the communication process, and scientist and journalist training for best communication practices. However, science literacy was the most dominant issue concerning science communicators and science communication scholars when trying to communicate about science and research (Treise & Weigold, 2002).

The public typically trusts information received by scientists because of their expertise in a particular field (Navarro, Tome, & Aldemita, 2014). Scientists' inclination to discuss their research with others directly impacts the public's ability to understand science (Lundy, Ruth, Telg, & Irani, 2006). However, scientists sometimes struggle to communicate effectively to the public because they are unsure of how to use words and language that resonates with lay audiences (Lundy et al., 2006). When scientists have a desire to communicate about science but are unsure how to execute effective communication, they will utilize journalists or communication experts to share their message (Treise & Weigold, 2002). Other scientists may not have the opportunity to work with a journalist or communication expert or, if so, may decline the opportunity (Treise & Weigold, 2002).

Faculty at land-grant institutions may be adept to communication about science because of the mission and purpose of land-grant institutions. In 1914, the Smith-Lever Act was enacted to create a Cooperative Extension Service (Association of Public and Land-Grant Universities [APLU], 2012). The Cooperative Extension Service was developed with the purpose of communicating research to the public (APLU, 2012). Deines (1990) explained the purpose of the Cooperative Extension Service: "the knowledge within the land-grant institutions should be made available to those not attending those institutions and should continue to be available throughout one's life. Thus was the university brought to the people" (p. 3).

According to Kyvik (2005), faculty that were published in more academic publications were more likely to produce science communication content intended for the public compared to less productive faculty. Additionally, social science faculty were more likely to engage with the public about science compared to faculty studying medicine or technology (Kyvik, 2005). Besley, Dudo, Yuan, and Lawrence (2018) noted scholars are more likely to participate in science communication when they expect to enjoy the activity they will participate in and if the scientist has had a favorable science communication experience in the past. Besley, Dudo, Yuan, and Lawrence (2018) also concluded age and gender can predict scientists' willingness to participate in science communication, but only slightly when compared to the aforementioned variables. Older scientists are less likely to face-to-face engagement and male scientists are more likely to participant in science communication with the news media (Besley, Dudo, Yuan, & Lawrence, 2018).

Conceptually, this study was guided primarily by the Excellence Theory. Excellence Theory was developed through the Excellence Study in which Grunig, Grunig, and Dozier (2006) examined over 300 organizations in three countries, including the United States, using a survey and follow-up interviews. The study included a sample of senior communication personnel, executive leaders, and employees (Grunig, Grunig, & Dozier, 2006). Two questions act as the foundation of the Excellence Theory, including how an organization is made more

effective through public relations and what public relations characteristics are most likely to make an organization effective (Grunig, Grunig, & Dozier, 2006). The Excellence Study combined the theory of organizational effectiveness and strategic management and public relations, as well as two-way communication. Two-way communication allows communicators to learn the needs of the audience the communicator intends to reach, gather information, and then disseminate information back to those audiences (Grunig, 1992). The process is continuous with constant interaction between the sender and receiver of information. The Excellence Theory implies communication is valuable to an organization, since communication leads to strategic relationships with the public (Grunig & Grunig, 2008; Ehling, 1992). This theory was tested through the Excellence Study and was confirmed through qualitative and quantitative results.

Besley, Dudo, Yuan, and Ghannam (2016) applied the Excellence Theory when they conducted qualitative interviews with science communication trainers about communication goals and determined science communication trainers for scientists should focus on the principles of public relations, rather than journalism. Besley, Dudo, Yuan, and Ghannam (2016) also determined scientists and journalists communicating about science may have different goals since scientists are much more focused on science whereas journalists have more broad goals that may simply be supported by science.

Purpose and Objectives

The purpose of this study was to describe the perceptions of the field of science communication held by interdisciplinary agricultural research center directors. The objectives that were used to guide the research were to:

1. Identify the science communication goals of interdisciplinary agricultural research center directors; and
2. Determine the interdisciplinary agricultural research center directors' beliefs of science communicators.

Methods

Phenomenological research techniques, which involves a particular set of participants with a purpose to explain those individuals' experiences, were used to address the purpose of this study (Ary et al., 2014). This research approach gives meaning to the individual experiences in a universal context, rather than simply describing the experience as an occurrence.

A purposive sample was narrowed using a list of (1) top American research institutions (Lombardi, Capaldi, Phillips, Abbey, & Craig, 2016), (2) land-grant universities (Association of Public and Land-Grant Universities, 2012), and (3) center primarily housed in a college that focuses on agricultural science. This sampling resulted in six land-grant universities that were also top 25 American research institutions. Then, interdisciplinary agricultural research centers were identified at each university, resulting in 108 centers. For the purpose of this study, an interdisciplinary agricultural research center was defined as an organized group of researchers with diverse perspectives evaluating an agricultural-related phenomenon through a variety of research methods and designs used in other disciplines. Two centers were randomly selected at each institution, and the directors were initially contacted via email by the researcher's advisor because the advisor was seen as a peer. The lead researcher then followed up with a telephone call to explain the research study and followed up again with an email asking for the director's participation in the study. Contact information, including email addresses and phone numbers, were obtained from the center's website. If no response was received from the participant after three days, another email was sent to the director. After another three days, if no response was

received, the director was eliminated from the sample and another center was randomly selected from the same university. Only one center at two universities were included in the sample because all other centers were contacted but declined to participate or did not respond. The participants were sent an email describing the purpose of the study, the importance of their participation as academic faculty, and the data collection procedures. Upon receiving the email, participants were then contacted via telephone to confirm a time and date for an interview. During this call, interview methods and informed consent were also discussed. Through this sampling, 10 centers from six land-grant universities were chosen that represented a wide range of disciplines within agricultural science and were spread across the United States, including all geographic regions except the Pacific Northwest. Figure 1 summarizes the sampling process used in this study.

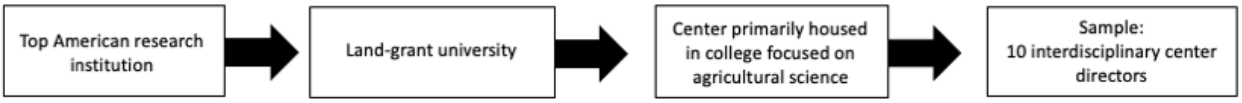

Figure 1. Summary of study sampling process.

A semi-structured interview protocol was developed based on the Excellence Study. The four questions analyzed in this study was part of a larger project. The questions analyzed in this study related to the participants' perceptions of science communication, including how science communication impacts society, how the science communication of agricultural topics impacts society, the goals of science communication, and who is best suited for the role of a science communicator. An expert panel comprised of individuals familiar with science communication and interdisciplinary research reviewed the interview protocol before the interviews. The individuals on the expert panel were university faculty whose research focused on agricultural communication and science communication and the director and an affiliate faculty of an interdisciplinary agricultural research center. Additionally, the interview guide was pilot tested with an individual who was similar to the participants of the study and revised to improve the flow and clarity of the interview questions.

Directive telephone interviews were conducted with the 10 interdisciplinary agricultural center directors at prominent research land-grant institution in the United States. The interviews took place within a two-week time frame in Fall 2017 to aid in the consistency of the interview. Alias names were given to each participant to protect the participants' anonymity. Field notes were taken during the interview, but interviews were also recorded for a complete transcription at a later date. The interviews lasted between 30 minutes and 70 minutes in length, averaging around 40 minutes.

The researchers made careful consideration to ensure truth and valid qualitative research as defined by Guba and Lincoln (1994), with includes credibility, transferability, dependability, and confirmability. The credibility of a study depends greatly on the participants included in the study and their accurate perception of the topics being examined. Lincoln and Guba (1985) suggested several analysis techniques to ensure credible studies, including participant observations, triangulation, peer debriefing, and member checking. For this study, peer debriefing was included to enhance the credibility of the study.

In a qualitative study, such as this one, transferability is most similar to the external validity of a quantitative study and refers to the generalizability of a study. Qualitative studies are not meant to be generalizable and only speak for the population being studied. However,

qualitative studies should be transferable in a way that allows the researcher to apply theoretical concepts found in the study to other contexts (Morse, 1994). Transferring the data and the application of the study is made possible by the researcher providing detailed descriptions. Transferability was ensured in this study by providing detailed descriptions of the decisions made and thorough descriptions of the data found.

Dependable studies are both consistent and accurate (Daymon & Holloway, 2002). In a dependable study, researchers must provide the rationale for all decisions made so that readers can interpret those decisions for themselves. Guba (1981) suggested keeping a reflexive journal to help the researcher track the decisions that were made throughout the analysis process. A reflexive journal was used by the researcher in this study and was often utilized for an inquiry audit during peer debriefing. Utilizing a reflexive journal gives the researcher the opportunity to critically think about their decisions, findings, biases, and opinions that were formed over time and then reflect on those things. Items in a reflective journal can also explain why the researcher made certain decisions that may otherwise be unclear.

Confirmability is another component of trustworthiness that can be exhibited through the use of a reflexive journal (Guba & Lincoln, 1982). Confirmability describes the accuracy of the findings and recommendations given the connection to the data collected in the study. Confirmability in this study was ensured through the use of a reflexive journal and interviewing multiple sources until data saturation was achieved.

The first step in organizing the data was to transcribe all the data collected during the interviews. Words were transcribed verbatim, and field notes were added to help give context and meaning. The researcher then became familiar with the data to help ease the analysis process. During this step, the researcher kept a reflective log noting initial thoughts or questions and how the discussion related to the study's objectives (Emerson, Fretz, & Shaw, 2001). Transcribed interviews were each read several times by the researcher and notes were made and revised throughout the process. Notes and data were analyzed using the constant comparative method (Bogdan & Biklin, 1992). The notes were compared to each other throughout the analysis process, as well as compared to the notes made during the interviews.

After the data were organized, the researcher coded the data by identifying common themes that emerged. Emerging themes can be noted through language, emotion, or even lack of response (Corbin & Strauss, 2008; Creswell, 2007). Inductive coding techniques, commonly used in qualitative data analysis, were specifically employed to analyze the themes (Ary et al., 2014). This process included categorizing codes, identifying relationships between codes, and developing major themes from the codes.

Findings

Participants of this study were directors at interdisciplinary agricultural research centers at top research land-grant universities. Directors worked at centers focused on a range of agricultural issues related to different disciplines, including animal science, ecology, plant science, food science, and economics. Participants were assigned an alias name. One woman and nine men were interviewed. Most participants had a doctoral degree, while one participant had a master's degree. The years of experience as director ranged from one year to 12 years. This information is summarized in Table 1.

Table 1
Participant Characteristics

Alias name	Gender	Education level	Years of experience	Research field
Mark	Male	Master's	12	Plant science
Nancy	Female	Doctorate	8	Animal science
Larry	Male	Doctorate	10	Food science
Tim	Male	Doctorate	10	Food science
David	Male	Doctorate	12	Agricultural economics
Mike	Male	Doctorate	3	International trade
Jeff	Male	Doctorate	3	Ecology
Jason	Male	Doctorate	6	Plant science
Brian	Male	Doctorate	6	Agricultural sustainability
Joey	Male	Doctorate	1.5	Animal science

To address the purpose of this research study, the researcher asked participants their opinions on communicating about science and agricultural science, the intended goals of science communication, and who is best suited to communicate about science. The following themes emerged: science communication as a service to the public, obligation to communicate about science, and the relationship between scientists and journalists.

Science Communication As A Service To The Public

"Science communication services" emerged as a theme and revealed the usefulness of communicating science to the public. In the conversations about perceptions and opinions of science communication, participants discussed how communicating about science to the public is "important for the well-being of society" (Tim). Brian said, "I don't know why we do science, except for society. So, if we can't communicate to society, we would have nothing." Science communication services can be categorized as services for public knowledge and services for public good.

Public knowledge

Participants expressed the notion of communicating science to the public as a service to public knowledge by aiding in people's ability to make educated decisions and solve problems more effectively. The slight majority of directors discussed a need or desire to communicate about science to help the public make decisions that were based in science and fact, rather than opinions and feelings, because "science provides factual information that is critical for reasonable decision-making," according to Jeff. David said, "Decision-makers oftentimes make decisions with very limited information and very little frameworks."

Most participants placed value in educating the public to make more informed life decisions. Joey explained:

> I think it's incredibly important and I can't emphasize that enough. There are so many decisions that are being made that affect society. Oh gosh, it affects everything that we do. And if those decisions aren't being formed by science it's largely best guesses or

perceptions that can lead to unpredictable results. If we can understand that and inform it in some way, we should.

Other participants also noted that by communicating science to the public, people could have improved abilities to solve problems in their own lives. “Educated citizens who are more informed about current issues” are prepared to address and solve problems, noted David. Participants explained that providing as much factual information as possible would equip people to solve problems and determine facts from opinions. Nancy said:

> I think a lot of the information that we get can be very helpful for individuals when they’re making choices about how they manage their households or their gardens or their farms or their communities. And so giving them sort of the latest and most up-to-date, most holistic views of that I think are very important because people are problem solving, and they will try to solve problems with whatever information they have available.

Public good

Most directors expressed science communication inspired actions of public good. Directors recognized a need to provide citizens with feedback on issues and scientific topics. Joey said, “There are a lot of questions that need to be answered as it relates to agricultural science, and through research and science is the only way to do that.”

Participants expressed a more pertinent need to provide feedback to the public when the participant’s center or research projects were funded through “tax dollars.” Jason explained:

> Whether [the public] knows it or not, they fund, to a great extent, what we do. And so it’s important for us to communicate to them to give a sense, or at least provide, feedback to them on the value of what they’re funding.

Nancy discussed how science communication also offers the public feedback on the work of policymakers. “We’re a public institution. And so that’s really controlled by state and federal governments, and so for people to understand how their policymakers are affecting education systems and research systems, I think is really important,” Nancy said.

Participants also said an important outcome of science communication was to excite children and adults about science. Participants, such as Nancy, also discussed encouraging excitement about science through science communication could lead to a “greater appreciation for the natural world.” Nancy said:

> And so [communication] creates this greater appreciation for the natural world and for these animal systems… So knowing that really cool, complex social behavior and how that’s regulated creates an appreciation and, hopefully, a love for that system that then will also be part of a motivation for conserving it.

Jason noted how the “race to space excited children about science and possibly led to those children finding an interest in science and technology, thus leading to a rise in innovation and technology that society now sees as those children are now adults creating new technology.” Jason referred to that excitement saying, “That excitement for science could really get people jazzed up and have people go into the agricultural industry.”

Many participants explained how science communication was valuable in creating awareness for science and the industry because participants represented a center that studied specific agricultural issues or whole sectors of the agricultural industry. Mark said his center's first goal is to create awareness of agricultural products. Nancy further explained how awareness impacts consumers: "I think it's also important for people, as consumers, to know how their products are being created and sort of have some understanding of that." Jeff said awareness is important because people need to understand where their food comes from.

Obligation To Communicate About Science

The expectation to communicate about science and who was the right person to communicate was also discussed by many participants. Some of the participants explained scientists and researchers at a public institution had an "obligation" to society to make research available and understandable to the public. Some directors, such as Jeff, noted that centers at public universities had "an obligation in this technical world to reach out and make our work more accessible." Participants had various opinions on what qualified as available and understandable. Tim said, "As scientists, we communicate to the public through our publications." Nancy said, "I do not know that we provide the best information enough." Brian explained:

> To be part of a public university, our role is to engage with the public. Not just to educate people's children and develop them for careers and to be good citizens, but also communicate across the age range and positions that people have in a state.

Many participants discussed the expectation to communicate about science to the public as a faculty member at a land-grant university. Mike said, "Communication is one of the three legs of the land-grant university system as Extension tries to transfer information to the public." Jason said a typical research faculty probably is not the best person to communicate, but Extension faculty are usually well equipped. Tim said he considers Extension when he thinks about communicating with the public. Some participants expressed that faculty with Extension appointments are the best, and sometimes the only, communicator in their center. Larry said, "We're not necessarily reaching out to the very broad public, although there's at least one member in our [center] who has an Extension appointment and, from time to time, will do that sort of thing specifically." Nancy said:

> One faculty member has an Extension appointment in our [center]. And that's actually the only person from our entire center who has that appointment. So it is her responsibility to create materials and things that would be specifically for [producers].

Participants also acknowledged that center administration, such as the director and associate directors, had limited time and insufficient funding for a full-time communication staff member. Some directors were the communicator for their center. Nancy writes material for her center's website. Joey said part of his job, as director, is to communicate to the public and make himself available for communication opportunities.

The Relationship Between Scientists And Journalists

Many directors had opinions of what it was like working with journalists and how journalists communicated about science based on their experiences working with them.

The large majority of participants noted that most scientists have little formal training in science communication, but acknowledged some scientists do a great job at communicating science, even without training. A few participants gave examples of their center's affiliate faculty struggling to work with media representatives and journalists. "The researchers aren't trained traditionally to communicate to the public. We are trained to communicate with other scientists. And the way that message is crafted and how you say things is really important," Joey said.

Jeff further explained the challenge that scientists lacking communication training face: "There are times that [scientists] get wrapped up in the minutia of issues that are really critically important to us and that can be confusing to members of the general public." Jason said some scientists are not good communicators of science: "I have been in meetings where [scientists] start talking to a legislator or a lay person, and the eyes glaze over pretty quick. They just go into so much detail." Jeff said he is part of professional societies that are encouraging scientists to become better communicators.

Some participants, such as Tim, were adamant that scientists were the best communicators of science. He said, "The best person to communicate science, really should be a scientist." Participants seemed to come to this conclusion based on their experiences with journalists. For example, Jason said, "There're so many journalists, if they don't have any kind of science background, they really get it wrong." Participants acknowledged some journalists represented science well, but most participants said journalists often could not communicate about science because they did not understand the complexity well enough to interpret findings, methodology, and processes. "A journalist isn't going to have the technical knowledge to understand the details of what needs to be communicated. And so, we get to a problem of sometimes oversimplification," said Brian.

All participants endorsed a partnership between scientists and journalists as the best way to communicate about science, as Nancy explained:

> It really is kind of a partnership. We can't expect the journalists to read our giant papers and pull out things to communicate to a particular audience. But at the same time, we can't be expected to do all of that ourselves as scientists.

Some participants also discussed the best science communicator would have an expertise that partnered the skills of a communicator and the knowledge of a scientist. Larry said:

> Potentially the best science communicators are people who are reasonably trained in both areas, who are strong writers or communicators. Whether they're journalists or not, I'm not sure is important, but somebody who is used to writing in that kind of genre or communicating in that way, but also has scientific training so they know what is or isn't current information.

Conclusions and Recommendations

The interdisciplinary agricultural research center directors in this study identified many goals of science communication, including knowledge, service, excitement, and feedback. All of

the goals that were identified by participants prioritized the public's interest. This finding aligns with findings from the National Academies of Science, Engineering, and Medicine (2016), which determined the public was typically a priority in the science communication process. Two-way communication, a vital tenet of the Excellence Theory, occurs when the public is engaged in science communication (Grunig, Grunig, & Dozier, 2006).

Previous literature identified low science literacy as a problem that impacts the public's ability to make effective decisions (Duncan & Broyles, 2006; Miller, 2004; Olper & Swinnen, 2013). As directors discussed knowledge gain as a goal of science communication, they would regularly relate the purpose to science literacy. Participants discussed the public needing information on issues related to science in order to make informed decisions about their own life, problems in society, and policy. Directors also discussed being a resource to decision makers to provide specific information about agricultural issues.

Participants of this study also believed an important goal of science communication was to promote or bring awareness to science, which aligns with Burns et al. (2003) definition of science communication. The directors spoke about the ability to bring general awareness to the agricultural industry and the topic their center studied, specifically.

The "obligation" to communicate about science was also a popular goal of science communication, according to the interdisciplinary agricultural research center directors. Directors that discussed an obligation to communicate about science and research felt obligated by their duty as a researcher at a public institution or, specifically, at a land-grant institution. By communicating about science, the land-grant faculty were bringing science to the people (Dienes, 1990). This may also be why some participants believed it was only the responsibility of faculty with an Extension appointment to participate in science communication.

Participants in this study also discussed sharing the responsibility of science communication with other individuals in their center, including communication staff or fellow administrators. The interdisciplinary agricultural research center directors discussed not having enough time or resources to effectively execute science communication. According to Grunig, Grunig, and Dozier (2006), various levels of an organization may have different perceptions or beliefs of the organization's public relation efforts, since each individual contributes in a different way,

Previous literature states that even though scientists struggle to connect with the public, information received by scientists is trusted by the public (Lundy et al., 2006; Navarro, Tome, & Aldemita, 2014). Participants in this study had similar views, discussing how scientists are often unsure how to engage the public or what language will resonate with the public, but agreed that scientists are the best communicators of science, especially when compared to journalists. However, scientists believed a partnership between scientists and journalists was the best way to communicate about science even though participants in the study discussed not having good experiences with journalists in the past.

Recommendations for future research include determining the impact science communication makes on the science literacy of audiences exposed to science communication practices. Furthermore, this study only explored interdisciplinary agricultural research center directors' perceptions of science communication but did not evaluate their center's science communication activities for effectiveness, which should be addressed in future research. It is expected that interdisciplinary agricultural research center directors have a view of science communication that is broad but limited in scope. It is recommended that future research explore the science communication perceptions of communication staff and affiliate faculty at

interdisciplinary agricultural research centers. Given the findings of this study, future research should determine if faculty at land-grant institutions are more inclined to communicate about science that faculty not associated with land-grant institutions. Similarly, future research should explore the science communication participation of Extension faculty. Future research should also apply the Excellence Theory to further explore the dynamics of effective communication, strategic relationships, and organizational effectiveness when applied to a science communication context.

Recommendations for practice include promoting stronger professional relationships between scientists and journalists or members of the media. Administration and faculty association with an interdisciplinary agricultural research center should take a more prominent role in educating the public about agricultural science issues, given their level of expertise and the public's inclination to trust scientists. Furthermore, policymakers should continue to use scientists as a source of information because of their expertise of particular topics and their inclination to serve the public.

References

Alpert, D. (1969). *The role and structure of interdisciplinary and multidisciplinary research centers*. Paper presented at Ninth Annual Meeting of the Council of Graduate Schools in the U.S., Washington, D.C. Retrieved from https://files.eric.ed.gov/fulltext/ED035363.pdf

Association of Public and Land-Grant Universities. (2012). About us. Retrieved from http://www.aplu.org/about-us/

Besley, J.C., Dudo, A.D., Yuan, S., & Ghannam, N.A. (2016). Qualitative interviews with science communication trainers about communication objectives and goals. Science Communication, 38(3), 356-381. doi:10.1177/1075547016645640

Besley, J.C., Dudo, A.D., Yuan, S., & Lawrence, F. (2018). Understanding scientists' willingness to engage. *Science Communication, 40*(5), 559-590. doi:10.1177/1075547018786561

Bogdan, R. C., & Biklen, S. K. (1992). Qualitative research for education (2nd ed.). Boston: Allyn & Bacon.

Burns, T. W., O'Connor, D. J., & Stocklmayer, S. M. (2003). Science communication: A contemporary definition. *Public Understanding of Science*, *12*(2), 183–202. doi:10.1177/09636625030122004

Bybee, R., McCrae, B., & Laurie, R. (2009). PISA 2006: An assessment of scientific literacy. *Journal of Research in Science Teaching*, *46*(8), 865–883. doi:10.1002/tea.20333

Clarke, B. (2003). Report: Farmers and scientists: A case study in facilitating communication. *Science Communication, 25*(2),198–203. doi:10.1177/1075547003259450

Corbett, C. F., Costa, L. L., Balas, M. C., Burke, W. J., Feroli, E. R., & Daratha, K. B. (2013). Facilitators and challenges to conducting interdisciplinary research. *Medical Care, 51*, S23–S31. doi:10.1097/mlr.0b013e31827dc3c9

Corbin, J., & Strauss, A. (2008). *Basics of qualitative research (3rd ed.): Techniques and procedures for developing grounded theory* Thousand Oaks, CA: SAGE Publications, Inc. doi:10.4135/9781452230153

Creswell, J. W. (2007). Research design: Qualitative and quantitative approaches. (2nd ed.). Thousand Oaks, CA: Sage.

Daymon, C., & Holloway, I. (2002). *Qualitative research methods in public relations and marketing communications*. New York, NY: Routledge.

Deines, V. P. (1990). Taking the university to the people: Seventy-five years of cooperative extension. Journal of Rural Studies, 6(3), 348-350. doi:10.1016/0743-0167(90)90092-m

Dijkstra, A. M., & Gutteling, J. M. (2012). Communicative aspects of the public-science relationship explored: Results of focus group discussions about biotechnology and genomics. *Science Communication, 34*(3), 363–391. doi:10.1177/1075547011417894

Duncan, D. W., & Broyles, T. W. (2006). A comparison of student knowledge and perceptions toward agriculture before and after attending a governor's school for agriculture. *NACTA Journal*, 50(1), 16–21. Retrieved from https://www.nactateachers.org/index.php/vol-50-num-1-march-2006-sp-1351200599/311-a-comparison-of-student-knowledge-and-perceptions-toward-agriculture-before-and-after-attending-a-governors-school-for-agriculture

Ehling, W. P. (1992). Public relations education and professionalism. In J. E. Grunig (Ed.), *Excellence in public relations and communication management* (pp. 439–464). Hillsdale, CA: Lawrence Erlbaum Associates.

Emerson, R.M., Fretz, R.I., & Shaw, L.L. (2011). *Writing ethnographic fieldnotes* (2nd ed.). Chicago, IL: University of Chicago Press. doi:10.7208/Chicago/9780226206868.001.0001.

Ezezika, O., & Mabeya, J. (2014). Improving communication in agbiotech projects: Moving toward a trust-centered paradigm. *Journal of Applied Communications*, *98*(1), 38–44. Retrieved from http://newprairiepress.org/jac/vol98/iss1/6/

Grunig, J. E., & Grunig, L. A. (2008). Excellence theory in public relations: Past, present, and future. Public relations research, 327-347. doi:10.1007/978-3-531-90918-9_22

Grunig, J. E., Grunig, L. A., & Dozier, D. M. (2006). The excellence theory. In C. Botan & V. Hazleton (Eds.), *Public relations theory II* (pp. 21–62). Mahwah: Lawrence Erlbauam Associates.

Guba, E. G. (1981). Criteria for assessing the trustworthiness of naturalistic enquiries. *Educational Communication and Technology Journal*, *29*(2), 75–91. Retrieved from https://pdfs.semanticscholar.org/8d32/23ed3c76cc4066ec894b5aca51c4f4028b7e.pdf

Guba, E. G., & Lincoln, Y. S. (1982). Epistemological and methodological bases of naturalistic inquiry. *ECTJ*, *30*(4), 233–252. doi:10.1007/978-94-009-6669-7_18

Guba, Y.S., & Lincoln, E.G. (1994). Competing paradigms in qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 105–117). Thousand Oaks, CA: Sage Publications.

Hartz, J., & Chappell, R. (1997). *Worlds apart: How the distance between science and journalism threatens America's future.* Nashville, TN: First Amendment Center

Hulcr, J. (2016, June 2). Universities need to communicate much more effectively about science (essay) [Web log post]. Retrieved from https://www.insidehighered.com/views/2016/06/02/universities-need-communicate-much-more-effectively-about-science-essay

Kleinman, D. & Powell, M. (2010). Consensus conference on nanotechnology. In D. H. Guston (Ed.), *Encyclopedia of nanoscience and society* (pp. 117-117). Thousand Oaks, CA: Sage Publications Ltd. doi: 10.4135/9781412972093.n67

Kyvik, S. (2005). Popular science publishing and contributions to public discourse among university faculty. *Science Communication, 26*(3), 288-311. doi:10.1177/1075547004273022

Lincoln, Y.S., & Guba, E.G. (1985). *Naturalistic inquiry*. Beverly Hills, CA: Sage Publications.

Lombardi, J. V., Capaldi Phillips, E. D., Abbey, C. W., & Craig, D. D. (2016). *The top American research universities: 2014 anual report.* Amherst, MA: The Center for Measuring University Performance.

Lundy, L. K., Ruth, A., Telg, R., & Irani, T. (2006). It takes two: Public understanding of agricultural science and agricultural scientists' understanding of the public. *Journal of Applied Communications, 90*(1), 55–68. doi:10.4148/1051-0834.1290

Mercier, S. (2015). *Food and agricultural education in the United States*. Washington, DC: AGree. Retrieved from http://www.foodandagpolicy.org/sites/default/files/AGree_Food%20and%20Ag%20Ed%20in%20the%20US_0.pdf

Miller, J. D. (2004). Public understanding of, and attitudes toward, scientific research: What we know and what we need to know. *Public Understanding of Science, 13*(3), 273–294. doi:10.1177/0963662504044908

Morse, J. (1994). *Critical issues in qualitative research methods*. Thousand Oaks, CA: Sage Publications.

National Research Council. (1988). *Understanding agriculture: New directions for education*. Washington, DC: National Academy.

Navarro, M., Tome, K., & Aldemita, R. (2014). *Academics and scientists as biotech communicators: Perspectives, capabilities, and challenges in Southeast Asia*. Paper presented at 13th International Public Communication of Science and Technology Conference, Salvador, Brazil. Retrieved from http://www.pcst-2014.org/pcst_proceedings/artigos/mariechel_navarro_kristine_tome_rhodora_aldemita_individual_papers.pdf

Nelkin, D. (1995) *Selling science: How the press covers science and technology*. New York: W.H. Freeman and Company.

Olper, A., & Swinnen, J. (2013). Mass media and public policy: Global evidence from agricultural policies. *The World Bank Economic Review, 27*(3), 413–436. doi:10.1596/1813-9450-6362

Paisley, W. J. (1998). Public communication campaigns: The American experience. In R. Rice and C. Atkin (Eds.). *Public communication campaigns*. Thousand Oaks, CA: Sage Publications, Inc.

Sapp, G. (1992). Science literacy: A discussion and an information-based definition. *College & Research Libraries*, *53*(1), 21–30. doi:10.5860/crl_53_01_21

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