SCIENCE COMMUNICATION SKILLS WITHIN THE AGRICULTURE INDUSTRY: WHAT ARE THE LEADERS IN INDUSTRY AND ACADEMIA SAYING?

by

GIAVANNA A. GONSALVES

(Under the Direction of Jessica Holt)

ABSTRACT

Professionals within the agriculture industry must be able to effectively communicate information about scientific and technological research and innovation—which are essential to the advancement of sustainable agriculture—to farmers, consumers, policymakers, and other stakeholders. However, in the age of mass and digital media, there is ample opportunity for information to be distorted and/or not effectively resonate with target audiences. Furthermore, scientists and other professionals often lack formal science communication training, and current science communication curricula are not fully evidence-based nor widely applied. Therefore, this research study explored agriculture industry leaders' and academia leaders' perspectives on the importance of various science communication skills for future professionals to have when communicating science within the agriculture industry. Implications and recommendations regarding university-industry collaboration and evidence-based science communication curricula were discussed.

INDEX WORDS: Science communication, Q methodology, University-industry collaboration, Curriculum development, Agriculture

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CHAPTER 1: INTRODUCTION

Need for the Study

Defining and Distinguishing the Importance of Science and Agriculture

Science and agriculture are arguably one in the same, as they are two bodies of knowledge and practices that are inextricably connected (Barrick et al., 2018; Bonnen, 2019; Huffman & Evenson, 2008; Wezel et al., 2020). Moreover, many sciences are foundational to agriculture, such as food science, crop and soil science, veterinary science, chemistry, engineering, entomology, and others (Weiner, 2003). Agriculture has even been considered the practical meeting place of science and technology (Hays, 2007), and this has become especially evident considering the advancement of agriculture over time (Alam et al., 2023; Doerfert & Miller, 2006; Liu et al., 2020). Numerous scientific and technological innovations (e.g., genetic engineering, CRISPR technology, drones) have coincided with the improvement of land management, higher crop yields, better food preservation, and a more sustainable agri-food system (Brown et al., 2019; Delgado et al., 2019; Fess et al., 2011; Khanna et al., 2023; Kumar et al., 2023). Furthermore, these future-forward practices and innovations could greatly contribute to successfully and sustainably feeding a growing population, which is projected to reach 10 billion by 2050 and require a 60%–100% increase in food production worldwide (Alfred et al., 2021; Bhat & Huang, 2021; McFadden et al., 2023; Monteiro et al., 2021).

Yet, alongside evolution and advancement of innovation in agriculture has also been an increase in the public's wariness of information (Koh et al., 2020; Moran et al., 2023). This phenomenon is especially evident regarding information that involves complex topics that challenge belief systems and personal values (Bavel et al., 2020) and is particularly relevant in terms of science- and agriculture-related information (Iyengar & Massey, 2019; Kovacheff et al., 2018; Zhang et al., 2023). However, for sustainable and innovative agricultural practices and technologies to persist, they must be supported by a variety of audiences, such as farmers, consumers, policymakers, and other stakeholders (Eidt et al., 2020; Lindberg et al., 2023). Effective communication of information is one of the key factors of building and maintaining stakeholder support (Alamanos et al., 2021; Bourne, 2016). Therefore, this study aimed to enhance science communication within the agriculture industry by identifying which science communication skillsets are most prioritized by leaders in the agriculture industry and in academia, as this information could be used to guide decision-making processes during the development of university-level science communication curricula that is both evidence-based and balanced in theory and practice, thus more intentionally preparing future agriculture professionals to more effectively communicate science.

Importantly, for the purposes of this study, science is operationally defined as any research or scientific and technological innovations that contribute to the advancement of a more sustainable and efficient agriculture system, agriculture is defined as the cultivation and dissemination of crops and livestock (Harris & Fuller, 2014), and science is assumed to be a fundamental part of agriculture. Furthermore, the agriculture industry is defined as the collection of enterprises within any sector related to agriculture, forestry, and natural resources, as they all play key roles in the production, dissemination, and protection of agricultural products (Jhariya et al., 2019; Yasmeen et al., 2021).

Communication Challenges Regarding Scientific and Agricultural Information

Public perceptions and trust in communication related to science, along with the intentional and unintentional dissemination of distorted information, raises the question of what effective science communication—which is defined in the present study as the use of appropriate skills, media, activities, and dialogue to produce personal responses (e.g., awareness, understanding, opinion-forming, interest, and enjoyment) to science (Burns et al., 2003)—looks like in the context of agriculture. As previously mentioned, science and agriculture are closely intertwined, and unfortunately science communication both within and between the agriculture industry and the public has not been immune to the harmful effects of communication-related challenges, such as distorted information and the abundance of channels through which it is relatively easy to distort information and disseminate it to large audiences (Chowdhury et al., 2024). Through broadcast news outlets, search engines, social media platforms, and even printed publications, three primary forms of distorted information have increasingly surfaced over the past few decades: fake news, misinformation, and disinformation (Aïmeur et al., 2023; Hadlington et al., 2023; Lwin et al., 2023). Fake news is fabricated information that resembles mainstream media content but is meant to spread lies instead of truth, misinformation is misleading information that often causes unnecessary panic or alarm, and disinformation is false information that is intentionally circulated to deceive audiences (Lazer et al., 2018).

It's also important to distinguish what the 'audience', or 'public', means to scientists, as this is a term that encompasses many different possible and plausible definitions (Besley & Nisbet, 2013). How scientists operationalize the term may determine how they disseminate information (Simis et al., 2016). Likewise, the diverse array of public stakeholders has varying perceptions of who is considered to be a 'scientist' as well as what 'science' entails, which influences how the public seeks, responds to, and uses information (Boulter, 1999; Gieryn, 2022; Nguyen & Catalan, 2020). These descriptive discrepancies further exasperate the challenge of communicating information effectively both between and among scientists and the public

(Weaver, 2020). Does the public perceive scientists as experts? Do scientists refer to themselves as experts? Can experts exist within the public? Is a citizen scientist considered to be an expert? Many self-proclaimed experts, such as the popular food blogger known as Food Babe (Zimmerman, 2021), voice their potentially imagined expertise on various media channels, but it has become harder and harder for people to discern who is telling the truth and who is setting agendas (Diekman et al., 2023).

Overall, it's difficult to discern who is primarily to blame for the public hesitancy surrounding science and agriculture—it could be scientists, the people and entities who create and spread misinformation, disinformation, and fake news, or a combination of both (Intemann, 2023; Iyengar & Massey, 2019; Lee et al., 2023). For this reason, it's necessary to consider the instances in which most people come to a consensus on what is scientifically true, yet certain groups of people's values, ideals, and ideologies lead them to reject that scientific 'truth' because it doesn't align with their ethical, moral, or religious values (Mannan & Farhana, 2020). It's also necessary to consider whether scientists need to focus not on the message itself, but rather on how to most effectively reach specific audiences without the information becoming distorted along the way. In other words, how can scientists, or any communicators of science, share a message and ensure that it remains the same over time and for a variety of audiences?

Consequences of Communication Challenges for Science and Agriculture

Importantly, communication challenges regarding scientific and agricultural information have resulted in consequences such as undermining democracy and diminishing support for effective agriculture-related policies and innovations that are both science- and evidence-based (Diekman et al., 2023), as well as consumers refusing to purchase various agricultural products and continuing to seek information from alternative sources that may be unreliable and inaccurate (Henderson et al., 2020).

For example, a peer-reviewed publication from 2018 about open scientific data on farmland earthworms was misconstrued as a warning for a ‘coming worm apocalypse’ through digital media platforms such as television and social media, as a global audience of millions re-interpreted the paper to mean that farmers have been hurting their farms by turning them into subterranean deserts. This media frenzy resulted in tensions between scientists and farming communities, thus jeopardizing participatory soil science (Stroud, 2019). Another example, known as the ‘Buttergate controversies’, involved a food blogger who tweeted that Canadian dairy farmers used palm fat as an additive in animal feed, thus changing the butter’s consistency and melting point and making it take longer to melt in the microwave when added to recipes. Social media users heavily weighed in on the food blogger’s theory and started demanding farmers to stop adding palm oil to animal feed, which ultimately led to a decrease of Canadian butter sales for months afterward (Chowdhury et al., 2023).

Additionally, it was found that many consumer and environmental groups believed gene-edited foods might pose risks and unintentional harmful consequences to consumers, farmers, and the environment while benefiting only a small number of powerful agribusiness actors (Bartkowski & Baum, 2019; Helliwell et al., 2022). Another study found that potential adopters of agricultural technologies that use artificial intelligence (AI) and require the collection of user data for decision making, such as agricultural decision support systems, perceived these types of technologies as less trustworthy due to their concerns about data security and the leakage of information during data sharing processes (Ferrag et al., 2020; Kukar et al., 2019). These are only a handful of examples of instances in which miscommunication and distorted information regarding science and technology resulted in tangible negative consequences for various actors within the agriculture industry.

The Need for Effective Science Communication Within the Agriculture Industry

Considering the many challenges involved with the effective dissemination of truthful information and the effects of distorted information related to agriculture in an age of mass media and agenda setting, it's important to examine how exactly scientists, experts, and any professionals working in the agriculture industry can be better prepared to effectively communicate science-related information to intended audiences. How can professionals communicating science work to mitigate misinformation, disinformation, and fake news? How can these professionals simultaneously strategically and critically consider the nuances in characteristics among various target audiences to build and maintain the public trust? There is a need for more effective science communication within the context of agriculture.

Some scholars have argued that one potential pathway forward may be found in a more equipped workforce through a more robust science communication curricula at the university level (McLeod-Morin et al., 2020; Mercer-Mapstone & Kuchel, 2017; Parrella et al., 2023; Washburn et al., 2022), as current science communication curricula are lacking in various ways and may need to be updated to match the needs of industry as well as be more dynamic and responsive to current technologies and media trends (Simis et al., 2016; Washburn et al., 2022).

Problem Statement

Science Communication Curricula at the University Level

Scientists often lack formal communications training during their degree programs (Simis et al., 2016; Washburn et al., 2022), meaning that scientists or other future professionals pursuing majors related to any science-based discipline (e.g., biology, agroecology, chemistry, etc.) commonly aren’t subjected to courses that explicitly and intentionally focus on communication skills. This is especially true for the hard sciences, or sciences in which the beliefs, attitudes, and perspectives of humans are rarely incorporated into the research lens (Dudo et al., 2021; Rowland & Kuchel, 2023).

Furthermore, the way in which information is shared about science and agriculture has changed over time, and this should be addressed in current science communication curricula (Fähnrich et al., 2021). Traditionally, agricultural extension and advisory service providers used in-person and group-based approaches to share information with farmers, who then applied the acquired information and knowledge to their practices with the goal of having a successful crop and ensuring food security. Consumers didn’t necessarily play a role in the knowledge sharing process. However, due to a lack of human resources and funding, as well as recent obstacles posed by COVID-19, extension and advisory service organizations found it difficult to provide farmers with usable and accessible agricultural information through traditional communication methods. Thus, the internet and the media have become more prominent platforms in which scientific and agricultural knowledge is exchanged, whether it’s between extension agents and farmers, farmers and farmers, extension agents and consumers, or farmers and consumers (Chowdhury et al., 2023).

Regarding consumers, they are increasingly looking for information about science and the agri-food system online when considering food purchasing decisions, and consumers now more often than ever use recommendations from other online consumers (Ismagilova et al., 2020; Nesmith, 2020). Also, Americans are seeking information that involves more than just cost and food quality, such as production practices and animal welfare in relation to agricultural products (Nesmith, 2020).

Additionally, universities often base their curricula on scholarly theories rather than work-based experience (Doerfert & Miller, 2006; Ellahi et al., 2019; Kemp et al., 2021; Mercer-Mapstone & Kuchel, 2017). This is problematic because professionals need more work-based experience and knowledge to more intentionally and effectively serve the institutions at which they are employed (Kemp et al., 2021; Mercer-Mapstone & Kuchel, 2017). Essentially, the current university system ultimately better prepares students to graduate and then become graduate students who conduct research rather than professionals within an industry (Kemp et al., 2021; Mercer-Mapstone & Kuchel, 2017).

Components of Effective Science Communication Curricula

Nonetheless, there is research in the literature that indicates the potential of more robust science communication curricula at the university level (McLeod-Morin et al., 2020; Mercer-Mapstone & Kuchel, 2017; Parrella et al., 2023; Washburn et al., 2022). Regarding advancing science communication within the agriculture industry, science communication research agendas could be incorporated more heavily into agricultural communication programs (Parrella et al., 2023). One study indicated that interdisciplinary agricultural research center directors from top research, land-grant institutions believe teaching and engaging in science communication is essential to serving the public (McLeod-Morin et al., 2020). Another study examined the demands and constraints on scientists trying to communicate science and, based on these findings, developed recommendations for enhancing science communication course content at the university level (Washburn et al., 2022). Finally, Mercer-Mapstone & Kuchel (2017) posited how science communication is taught most effectively when the skills involved are tailored to specific educational contexts, and they conducted a study that resulted in a teaching resource for undergraduate science communication curriculum development that is evidence-based and reflective of theory and practice.

As mentioned previously, there is a need for more balanced focus between theory and practice within university-level curriculum, and one way to balance curriculum foci and goals is to incorporate more effective and empirically supported work-based communication curriculum into university-level courses. This can be done through effective university-industry collaboration (UIC), a process in which universities consult with industries of interest and engage in discussions regarding what both sides want to incorporate into curriculum (Erkarslan & Aykul, 2018; Ishengoma & Vaaland, 2016; Nangia & Pramanik, 2011; Spier, 1995). Additionally, through UIC, universities can better prepare students to not only become more effective science communicators but also increase students' employability (Kemp et al., 2021; Rowland & Kuchel, 2023).

Exemplary Institutions Regarding Opportunities for Enhancing Science Communication

To mark an example of an institution that supports and engages in scientific and technological innovation, often within the context of agriculture and all with the goal of serving Georgia's citizens, The University of Georgia (UGA) is a land-grant university that heavily focuses on the improvement and advancement of agriculture through education, service, research, and innovation (*Office of the President,* 2023). One way it fulfills its land-grant mission is through the Institute for Integrative Precision Agriculture (IIPA), established in 2022 with the purpose of advancing UGA's agricultural technology research (Integrative Precision Agriculture, 2023). Furthermore, UGA's land-grant mission involves supporting and developing the economy. UGA fulfills this part of its mission by having an $8.1 billion impact on Georgia's economy annually (*Office of the President*, 2023).

Within a broader context, the state of Georgia has a robust agricultural industry, as agriculture contributes approximately $69.4 billion to the state's economy annually (*About Georgia Ag*, 2023). It's clear that both UGA and the agricultural industry within Georgia are key players in Georgia's economy, and they have dramatic economic impacts on Georgia citizens. Therefore, it's important for Georgia citizens to have a high amount of trust in Georgia's agricultural industry so they can continue to feel comfortable supporting it as an industry. Also, while much of their trust is a product of how Georgia's agricultural industry communicates with the public, it's part of UGA's land-grant mission to help facilitate that effective communication—not just for the sake of supporting Georgia's economy, but also for the sake of better serving Georgia's citizens (*Office of the President*, 2023).

The present study contributes solutions to the need for more effective science communication within the agricultural industry by identifying which skills related to science communication are perceived as most necessary for future professionals to have according to leaders in Georgia's agricultural industry and leaders in academia at UGA, as Georgia's agricultural industry and UGA's land-grant mission are exemplary of the importance of science, agriculture, and communication. This information could help strengthen the university-industry relationship and encourage more meaningful conversation regarding science communication curricula development at the university level, ultimately resulting in better prepared students as science communicators at the professional level, more effective science communication within Georgia's agricultural industry, and a greater number of Georgia citizens who trust and support Georgia's agricultural industry. Methods and findings from this study could be applied to broader contexts, such as curricula development at other land-grant universities and exploring necessary communication skills within agriculture industries in other states.

CHAPTER TWO: CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

Scientific and Technological Innovation in Agriculture

Agriculture is broadly defined as a form of land use and economy that resulted from the combination of cultivation, domestication, and dissemination of agricultural products (Harris & Fuller, 2014). It is arguably the reason for the development of society, serving as the primary driver behind a relatively reliable and consistent food system, the opportunity for the specialization of labor, and the formation of distinct economic and social classes (Gowdy & Krall, 2014). While the first occurrence of this paradigm-shifting practice of systematic cultivation and domestication was most likely around 11,000 years ago in the Near East (Zeder, 2011), it wasn't until 1862 that the U.S. signed into law the Morrill Act and land was donated to each state for the establishment of colleges to provide education to common people and instruction in primarily agriculture. This act, also known as the land-grant act, has resulted in more than 100 land-grant institutions in the U.S. today (Croft, 2019). The University of Georgia is one of them, chartered as a public university in 1785 and established as a land-grant university in 1872 (*Public Service and Outreach*, 2023).

Additionally, the United States Department of Agriculture (USDA) was established alongside the Morrill Act of 1862 to positively impact the lives of generations of Americans through agriculture, economic development, science, and natural resource conservation (USDA, 2023). Following the establishment of the USDA and the Land Grant Colleges in 1862, the Hatch Act of 1878 provided financial support to conduct agricultural research programs at State Agricultural Experiment Stations (SAES) in the United States. These research programs involve all aspects of agriculture, from soil and water conservation and use; plant and animal production and wellbeing; forestry and land management; rural and community development; sustainable agriculture; et cetera (USDA, 2023).

The Knowledge Economy (KE) Framework Applied to the State Level

The development and implementation of these acts and institutions indicate how important agriculture is for the economy and society (Moser, 2020). They make evident the need for innovation in agriculture, which drives efficiency and sustainability (Herrero et al., 2021; Qayyum et al., 2023; Rose et al., 2021). However, for sustainable and innovative agricultural practices and technologies to persist, they must be supported by a variety of audiences, such as farmers, consumers, policymakers, and other stakeholders (Eidt et al., 2020; Lindberg et al., 2023).

Effective communication of information is one of the key factors of building and maintaining stakeholder support (Alamanos et al., 2021; Bourne, 2016), an important point considering the United States (along with other developed countries) is involved in a Knowledge Economy (KE). KE, which was developed as a concept in the 1960s by various economic and social scholars (Powell & Snellman, 2004), refers to an economy in which economic activities rely on non–routine, non-manual technical skills, intellectual creativity, and scientific knowledge, and it is considered to be the main engine of economic growth in developed countries (Berkes & Gaetani, 2023; Powell & Snellman, 2004). KE has also been described as "the accumulation of capital, technology, technology-relevant capabilities, and science in the conduct of productive activity" (Unger, 2022, p. 20) Communication plays an important role in Kes because it is the primary way in which information is shared and received and then understood and applied (Hadad, 2017; Tiwari, 2022), thus allowing for more and more individuals and entities to enter KE and contribute to, as well as benefit from, its growth and expansion (Unger, 2022).

Within a global or national economy, KE consists of four primary pillars: economic and institutional regime, well-educated and skilled population, information and communication technology infrastructure (ICT), and innovation system (Chen & Dahlman, 2005). Therefore, KE involves every economic sector and is very relevant in terms of the agriculture industry, from the global, national, regional, and state perspective (Tiwari, 2022; Unger, 2022). For the purposes of the present study KE was used as a framework for conceptualizing the flow of information and productivity related to agriculture within the context of a state-level economy. Therefore, Table 2.1 defines the four pillars while also establishing a state-specific context for the purposes of framing the study.

Table 2.1.
The Knowledge Economy (KE) Framework Applied to the State Levels

Pillar	General description (broad context)	State-level description (specific context)
Economic and institutional regime	Any regime that provides incentives encouraging the use and spread of existing and new knowledge in an efficient manner, thus supporting creation and innovation. The economic environment is favorable to market transactions and the government encourages entrepreneurship and invests in knowledge sharing.	The state government and economy of Georgia, both of which provide incentives to foster and support knowledge sharing and economic growth (MacLeod & Urquiola, 2021)
Well-educated and skilled population	A population that forms, disseminates, and applies knowledge in an efficient manner. Education plays a crucial role here, as it is necessary for the acquiring and application of	Georgia citizens and Georgia's agriculture industry, as these comprise the individuals and entities who create, share, and apply knowledge to apply and innovate. Future professionals

	knowledge and technological/scientific advancement.	in the agriculture industry also exist here.
Information and communication technologies (ICT) infrastructure	Infrastructure that facilitates the communication, dissemination, and processing of information and technology. As efficiency of facilitation increases, there is greater communication, productivity, and output.	Infrastructure within Georgia that facilitates the communication, dissemination, and processing of information and technology—e.g., social media, television, Extension, websites, etc.
Innovation system	Systems that involve firms, universities, research centers, think tanks, etc. that use and apply knowledge to create new technology, leading to productivity growth.	The University of Georgia as a research center, as it is an institution with a land-grant mission to apply knowledge and contribute to productivity growth. Students at the university are also found here, as they are learners and researchers that have the potential to contribute to productivity growth as future professionals.

A visual conceptualization of this framework can be seen in Figure 2.1. All pillars contribute to a KE, but they each play a different role in the development of it. Pillar 2 involves any professionals within the agriculture industry in Georgia as well as Georgia citizens (which could include policymakers, consumers, farmers, etc.), while Pillar 4 involves the University of Georgia as an educational institution and a research center in which students are trained to be future professionals within the agriculture industry. Pillar 3 involves the infrastructure available for disseminating and receiving information, which is used among actors within each of the other three pillars. Finally, Pillar 1 involves the government and economy of Georgia, which incentivizes research, innovation, and productivity through funding and investments in various institutions and infrastructures, a viable market economy, and related policies (MacLeod & Urquiola, 2021); Georgia Department of Education, 2023).

Figure 2.1.

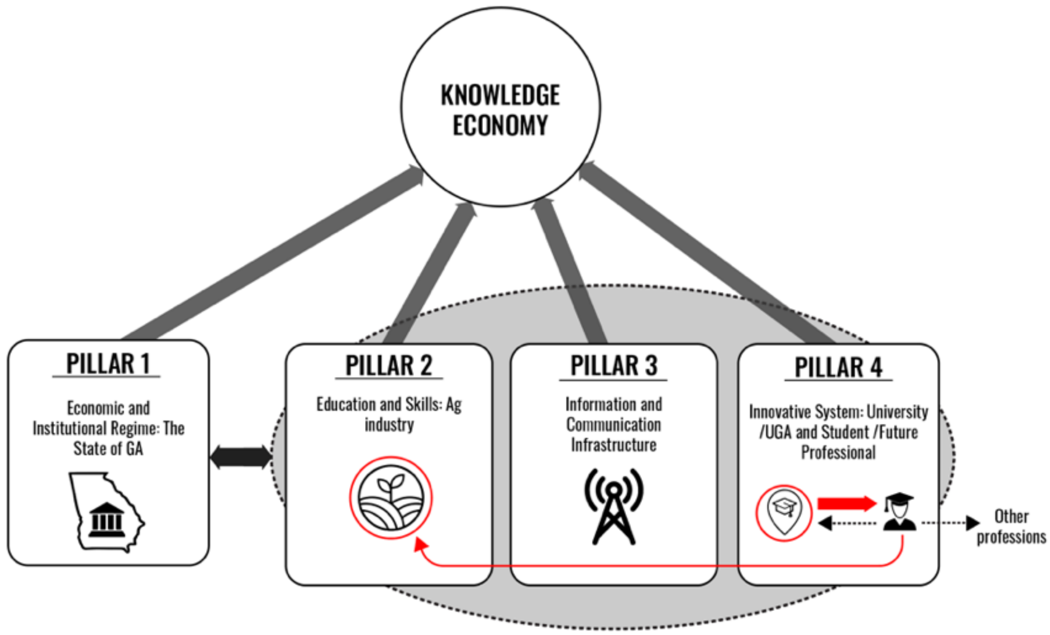

Figure 2.1
The KE Framework Applied to the State Level

A double-sided arrow exists between student/future professional and the university because students don't always join the workforce after graduation—a portion enroll in graduate school and contribute their knowledge and skills back to the university through engaging in research and further knowledge acquisition and development (Li, 2022). It's also important to note that not all students join the agriculture industry as professionals, even if they were enrolled in degree programs that intend to prepare them for that specific workforce. This is why an arrow exists extending from the student to 'Other professions'. Nonetheless, even if students enter different workforces as professionals, they are still part of the KE as educated and skilled citizens who can share and apply their knowledge in other areas.

One final point regarding the KE framework applied to the state level is that there was a specific knowledge area under consideration for the context of the present study: science communication skills. While KE generally involves all aspects of knowledge, especially related to scientific and technological innovation (Li, 2022; Unger, 2022), the framework used here involves specifically the knowledge of effectively communicating science. In other words, by using this framework it is assumed that the sharing and application of effective science communication skills among the university, the agriculture industry, students, and future professionals will foster greater science communication within the agricultural industry, ultimately benefiting all actors in the KE system.

Universities will have more knowledge regarding how to best train students to be effective science communicators as professionals within the agriculture industry, students will have greater employability, the agriculture industry will have professionals who are better equipped to communicate about science, and Georgia citizens will be more effectively engaged in communication efforts about the scientific and technological research and innovation occurring within Georgia's agriculture industry (Kemp et al., 2021; Rowland & Kuchel, 2023). In turn, Georgia citizens will be in greater support of Georgia's agricultural industry, thus fostering productivity and economic growth, all of which contribute to Georgia's economy and beyond and thus encourage Georgia's state government to further incentivize research and innovation within Georgia's agriculture industry and universities. It is a circular economy, growing and expanding based on its internal actors (Unger, 2022).

However, it's also important to note that there are external factors that and actors who can influence the state-level KE, such as national and global economies and politics (Chen & Dahlman, 2005). Regarding the present study, it was assumed that study participants considered external factors while completing the activities within the study but focused primarily on industry- and/or academia-related dynamics within Georgia, specifically. For example, a participant may have considered the influence of an upcoming national presidential election on the dynamics of science and science communication (e.g., the president's political views about science may affect trust in science regardless of other entities' communication efforts (Kreps & Kriner, 2020), but he or she considered how this would affect citizens, industry, and universities in Georgia specifically rather than from a national or global perspective.

The University-Industry Collaboration (UIC) Model

Focusing more closely on the Information and Communication Technology (ICT) Infrastructure pillar of the KE, one way in which actors within the KE communicate information is through conversation and collaboration (Hadad, 2017; Li, 2022; Tiwari, 2022; Unger, 2022). For the present study, professionals within the agriculture industry and professionals within academia have the potential to share their knowledge regarding science communication skills, as the former is able to give insight into practical, work-based skills and the latter is able to give insight into theory-based skills, both of which would inform more effective science communication curricula at the university level. This process is known as university-industry collaboration (UIC), in which universities consult with industries of interest and engage in discussions regarding what both sides want to incorporate into curriculum (Erkarslan & Aykul, 2018; Ishengoma & Vaaland, 2016; Nangia & Pramanik, 2011; Spier, 1995).

Curricula that are exemplary results of this process include a teaching resource for undergraduate science communication curriculum development (Mercer-Mapstone & Kuchel, 2017), a co-operative model based on a Plan–Do–Study–Act cycle that was applied in the curriculum design of two courses in welding within a manufacturing engineering master's program (Valiente Bermejo et al., 2022), a co-designed and co-delivered curriculum focused on enhancing students' data literacy skills for students to succeed in the labor market within the digital era (Taş, 2023), and a 200-level course and an advanced 400-level course developed to better train life science majors in communication theories and practices (Kelp & Hubbard, 2021).

The addition of UIC to the KE framework at the state level can be seen in Figure 2.2. Universities, or more specifically experts in academia, converse with the agriculture industry, or more specifically professionals within the agriculture industry. Furthermore, the goal of UIC is for engagement to occur in equal proportion between the two actors, thus collaboration is in the center of a communication scale, in which silence (zero collaboration) occurs on one end of the spectrum, and conflict (also zero collaboration) occurs on the other end of the scale. Silence occurs when there is no infrastructure in place for conversation to occur, and conflict occurs when either entity is unwilling to contribute to the conversation in a meaningful or productive manner (Rajalo & Vadi, 2017; Rose-Anderssen & Allen, 2008; Wright, 2017). Importantly, this collaboration method acts as the conduit, or infrastructure, through which information and knowledge can be exchanged, hence why it is placed among Pillar 3. This collaboration also allows for the agriculture industry, or educated and skilled population, to more closely interact with the university, or innovative system, thus allowing for the university to more intentionally prepare the student as a future professional in the agriculture workforce.

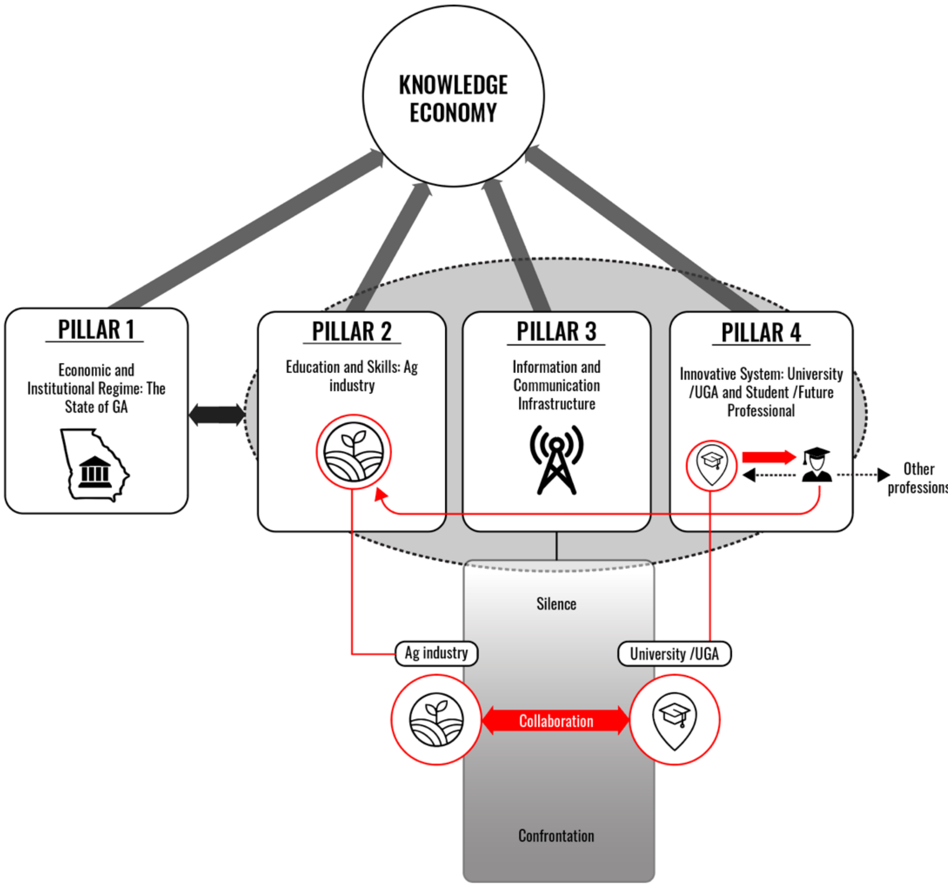

Figure 2.2
The KE Framework Applied to the State Level

Purpose, Objectives, and Design Overview

The purpose of this study was to explore shared and nuanced viewpoints among leaders in Georgia's agricultural industry and among leaders in academia at the University of Georgia (UGA) regarding the importance of various science communication skills within Georgia's agricultural industry, as well as to understand how to most effectively gain meaningful insight regarding the shared viewpoints of leaders in industry and academia to begin forming a base for more effective science communication curriculum at the university level. Using a conceptual framework consisting of the pillars of the KE and the addition of the UIC model, the following research objectives guided this study for chapters 3 and 4:

Chapter Three: Exploring perceptions of the importance of science communication skills in Georgia's agricultural industry

1. Describe the sociodemographic characteristics of leaders in Georgia's agricultural industry.
2. Explore Georgia's agricultural industry leaders' perceptions of levels of importance of various skills related to communicating science within Georgia's agricultural industry.
3. Examine shared and nuanced viewpoints among various agricultural industry leaders in Georgia regarding the level of importance of various skills related to communicating science within Georgia's agricultural industry.

Chapter Four: Informing science communication curriculum development: Academia leaders' perceptions of important science communication skills within the agriculture industry

1. Describe the sociodemographic characteristics of leaders in academia within UGA's College of Agricultural and Environmental Sciences.
2. Explore academia leaders' perceptions of levels of importance of various skills related to communicating science within Georgia's agricultural industry.
3. Examine shared and nuanced viewpoints among leaders in academia regarding levels of importance of various skills related to communicating science within Georgia's agricultural industry.

Design Overview: The study took place between October 2023 and February 2024, and participants were contacted and recruited via email. Q methodology was used to achieve the research objectives. An online activity involving a Q sort with a prompt and a Q set (a list of science communication skills extracted from relevant literature), along with a post-survey related to insights from the sorting process and socioeconomic demographic information, was developed and distributed through QMethod Software (qmethodsoftware.com). The same software was used to analyze data and extract factors to inform conclusions and recommendations.

Definition of Terms

The key terms below are presented throughout the research:

- *Science*— any research or scientific/technological innovations that contribute to the advancement of a more sustainable and efficient agriculture system
- *Agriculture*— a form of land use and economy that resulted from the combination of cultivation, domestication, and dissemination of agricultural products (Harris & Fuller, 2014)
- *Agriculture industry*— The collection of enterprises within any sector related to agriculture, forestry, and natural resources
- *Concourse*— a collection of all potential thoughts or opinions about a specific topic (Brown, 1993)
- *Knowledge Economy (KE)*— An economy in which economic activities rely on non–routine, non-manual technical skills, intellectual creativity, and scientific knowledge in the conduct of productive activity (Berkes & Gaetani, 2023; Powell & Snellman, 2004; Unger, 2022)
- *P set (P sample)*— participants of the study who are purposefully and intentionally chosen (Stenner & Watts, 2012)

- *Q methodology*— a research method created by William Stephenson in 1935 that evaluates participants' subjectivity in a research study through factor analysis (Brown, 1980)
- *Q set (Q sample)*— a set of intentionally selected statements derived from the concourse that represent relevant opinions about the topic under discussion (Brown, 1980)
- *Q sort*— a method technique used in a Q-study in which participants engage in rank ordering of the Q set (McKeown & Thomas, 2013)
- *University-Industry Collaboration (UIC)*— a process in which universities consult with industries of interest and engage in discussions regarding what both sides want to incorporate into curriculum (Erkarslan & Aykul, 2018; Ishengoma & Vaaland, 2016; Nangia & Pramanik, 2011; Spier, 1995)
- *Science Communication*— The use of appropriate skills, media, activities, and dialogue to produce personal responses (e.g., awareness, understanding, opinion-forming, interest, and enjoyment) to science (Burns et al., 2003)

Limitations

This study was limited by the following:

1. A very select group of individuals were selected as participants, as they were all past, current, or board members of Advancing Georgia's Leaders in Agriculture and Forestry (AGL), or deans of and department chairs within the College of Agricultural and Environmental Sciences (CAES). Therefore, conclusions from this study are only generalizable to these groups.
2. This study was conducted in Georgia and focused on Georgia's agricultural industry as well as CAES with very specific participants. Therefore, the conclusions from this study

are only generalizable to the individuals who represented Georgia's agricultural industry and CAES within this study.

3. Q methodology was used to gain nuanced perspectives among target participant groups, but there are other methods and methodologies (e.g., focus groups, interviews, surveys, Delphi methods, etc.) that could've been used to achieve the same research objectives but with differing results.
4. The agriculture industry, academia, and the media landscape are constantly evolving (Alam et al., 2023; Hadlington et al., 2023; Moser, 2020), and while the present study is future-oriented, it only applies to a specific timeframe. Continuous research and university-industry collaboration is needed to ensure consistently up-to-date and relevant science communication practices and curriculum.
5. Leaders in industry and academia are not the only actors involved in the process of science communication within the agriculture industry—further research is needed regarding other (particularly underrepresented) stakeholder's perceptions of the importance of various science communication skills, or at least what effective science communication means to them (Canfield et al., 2020)

Assumptions

The following assumptions were present in this research:

1. Science is a fundamental part of agriculture.
2. Participants had personal definitions and mental concepts of what science communication means.
3. Participants believed science communication plays a role currently within the agricultural industry (McLeod-Morin et al., 2020)

4. Participants fully understood and honestly responded to all questions and prompts during data collection.
5. Questions and prompts were made as clear as possible for study participants (e.g., clear instructions for the sorting processes, provided definitions for ambiguous terms, etc.).
6. Participants received sufficient time to complete the surveys and sorting activities.
7. University and industry are capable and willing to share knowledge with each other regarding how to identify and develop necessary skills for employment and growth within the industry (Li, 2022)
8. University researchers, faculty, staff, and students are capable and willing to work together to develop, implement, and learn from an empirically based curriculum (Valiente Bermejo et al., 2022)
9. Study participants considered external factors related to KE while completing the study but focused primarily on industry- or academia-related dynamics within Georgia, specifically.
10. Better science communication within Georgia's agricultural industry will result in a higher level of trust among Georgia citizens in Georgia's agricultural industry, thus resulting in a more supported agricultural industry (Intemann, 2023)
11. Georgia's agricultural industry receiving more support will benefit Georgia's economy and citizens.

CHAPTER THREE: EXPLORING PERCEPTIONS OF THE IMPORTANCE OF SCIENCE COMMUNICATION SKILLS IN GEORGIA'S AGRICULTURE INDUSTRY[1]

[1] Gonsalves, G., Holt, J., Borron, A., Lamm, A.J. *To be submitted to Journal of Agricultural Communications*

Abstract

Science is an integral part of agriculture, and scientific and technological innovation within agriculture are becoming more and more complex and advanced, especially alongside the expansion of the Knowledge Economy (KE). These advancements contribute to the sustainability of agriculture, but for these sustainable innovations and practices to persist, multiple types of stakeholders must support them. Effectively communicating science with various stakeholders is essential to building and maintaining their buy-in and support for the agriculture industry, but this has become increasingly difficult due to several communication challenges. One pathway forward to facing these challenges could be by developing an effective science communication curriculum at the university level through fostering university-industry collaboration (UIC). Thus, Q methodology was used to explore nuanced perspectives among agriculture industry leaders in Georgia regarding the importance of science communication skills within the context of the agriculture industry. Four prevailing factors emerged, each representing a prioritized skillset: Strategize on a Budget (F1), Empathize with Audiences and Leverage Communication Technology (F2), Exude Credibility and Communicate Quickly (F3), and Exude Confidence and Engage Audiences (F4). Descriptions of each factor are discussed and compared, and implications and recommendations for the development of science communication programs and curricula are considered. Future research opportunities that could further establish Q methodology as a useful means of understanding industry perspectives and various aspects of science communication within the agriculture industry are also discussed.

Introduction

Agriculture plays an essential role in sustaining a growing population, which is projected to reach 10 billion by 2050 and require a 70% increase in food production worldwide (Alfred et al., 2021; Bhat & Huang, 2021; McFadden et al., 2023; Monteiro et al., 2021). Through sustainable agricultural systems and practices, the current needs of society can be met without compromising the needs of future generations (Lal, 2021). Furthermore, scientific and technological innovations are what drive sustainability (Herrero et al., 2021; Qayyum et al., 2023; Rose et al., 2021). Drones, genetic engineering, and big data analysis are just a few examples of innovative practices and applications that have coincided with the improvement of land management, higher crop yields, better food preservation, and a more sustainable agri-food system (Brown et al., 2019; Delgado et al., 2019; Fess et al., 2011; Khanna et al., 2023; Kumar et al., 2023), thus indicating that science and agriculture are closely intertwined (Barrick et al., 2018; Bonnen, 2019; Hays, 2007; Huffman & Evenson, 2008; Weiner, 2003; Wezel et al., 2020).

However, for sustainable and innovative agricultural practices and technologies to persist, they must be supported by a variety of audiences, such as farmers, consumers, policymakers, and other stakeholders (Eidt et al., 2020; Lindberg et al., 2023). Yet, recent studies have indicated that, especially after the COVID-19 pandemic, trust in science and scientists has begun decreasing (Kennedy & Tyson, 2023; Kreps & Kriner, 2020), and there has been more notable consumer pushback against many innovative and future-forward agricultural practices and innovations (Gibson et al., 2023; Little et al., 2023). These phenomena are likely a result of a number of communication-related challenges, such as the distortion of information and the abundance of channels through which it is relatively easy to distort information and disseminate it to large audiences (Chowdhury et al., 2024; Hadlington et al., 2023). Therefore, more effective communication of information is necessary for building and maintaining stakeholder support (Alamanos et al., 2021; Bourne, 2016).

Moreover, scientists and professionals within the agriculture industry typically receive some sort of higher education degree during their career, (Simis et al., 2016; Washburn et al., 2022), but their degree programs often lack formal or sufficient communication training, let alone science communication training, which is problematic for future workforce readiness (McLeod-Morin et al., 2020; Mercer-Mapstone & Kuchel, 2017; Parrella et al., 2023; Washburn et al., 2022). For example, science communication curricula need to be updated to match the needs of industry as well as be more dynamic and responsive to current technologies and media trends, as the way in which information is shared about science and agriculture has changed over time (Fähnrich et al., 2021). Consumers, too, have begun acquiring and exchanging information in new ways, as they increasingly look for information about science and the agri-food system online and among other consumers when considering food purchasing decisions (Ismagilova et al., 2020; Nesmith, 2020). Also, current university-level science communication curricula are often based on scholarly theories rather than work-based experience (Doerfert & Miller, 2006; Ellahi et al., 2019; Kemp et al., 2021; Mercer-Mapstone & Kuchel, 2017), even though professionals need more work-based experience and knowledge to more intentionally and effectively serve the institutions at which they are employed (Kemp et al., 2021; Mercer-Mapstone & Kuchel, 2017).

Therefore, this study aimed to enhance science communication within the agriculture industry by identifying which science communication skillsets are most prioritized by various leaders in the agriculture industry and in academia, as this information could be used to develop a university-level science communication curriculum that is both evidence-based and balanced in theory and practice and thus can more intentionally prepare future agriculture professionals to more effectively communicate science to various audiences.

Literature Review and Conceptual Framework

Innovation through science and technology serves as an essential driver in agriculture as demands for efficiency and suitability are on the rise (Herrero et al., 2021; Qayyum et al., 2023; Rose et al., 2021). Yet, as mentioned previously, innovation must be supported by a variety of stakeholders to persist (Eidt et al., 2020; Lindberg et al., 2023). Science communication, which is defined in the present study as the use of appropriate skills, media, activities, and dialogue to produce personal responses to science (e.g., awareness, understanding, opinion-forming, interest, and enjoyment) (Burns et al., 2003), is necessary for building and maintaining stakeholder support (Alamanos et al., 2021; Bourne, 2016). This is an important point considering the United States (along with other developed countries) is involved in a knowledge economy (KE).

The KE, which was developed as a concept in the 1960s by various economic and social scholars (Powell & Snellman, 2004), refers to an economy in which economic activities rely on non–routine, non-manual technical skills, intellectual creativity, and scientific knowledge, and it is considered to be the main engine of economic growth in developed countries (Berkes & Gaetani, 2023; Powell & Snellman, 2004). The KE has also been described as "the accumulation of capital, technology, technology-relevant capabilities, and science in the conduct of productive activity" (Unger, 2022, p. 20). Communication plays an important role in KEs because it is the primary way in which information is shared and received and then understood and applied (Hadad, 2017; Tiwari, 2022), thus allowing for an ever-increasing number of individuals and entities to enter the KE and contribute to, as well as benefit from, its growth and expansion (Unger, 2022).

Within a global or national economy, the KE consists of four primary pillars: economic and institutional regime, well-educated and skilled population, information and communication technology (ICT) infrastructure, and innovation system (Chen & Dahlman, 2005). Therefore, the KE involves every economic sector and is very relevant in terms of the agriculture industry, from the global, national, and state perspective (Tiwari, 2022; Unger, 2022). For the purposes of the present study, the KE was used as a framework for conceptualizing the flow of information and productivity related to agriculture within the context of a state-level economy. Georgia is the state of interest, as Georgia's agriculture industry contributes approximately $69.4 billion to the state's economy annually (*About Georgia Ag*, 2023), and Georgia is home to a land-grant university known as the University of Georgia (UGA), which also has an $8.1 billion impact on Georgia's economy annually and has a land-grant mission to teach, serve, engage in research, and foster scientific and agricultural innovation (*Office of the President* 2023). Therefore, Table 3.1 defines the four pillars while also establishing a state-specific context for the purposes of framing the study.

Table 3.1
The Knowledge Economy (KE) Framework Applied to the State Level

Pillar	General description (broad context)	State-level description (specific context)
Economic and institutional regime	Any regime that provides incentives encouraging the use and spread of existing and new knowledge in an efficient manner, thus supporting creation and innovation. The economic environment is favorable to market transactions and the government encourages entrepreneurship and invests in knowledge sharing.	The state government and economy of Georgia, both of which provide incentives to foster and support knowledge sharing and economic growth (MacLeod & Urquiola, 2021); Georgia Department of Education, 2023).

Well-educated and skilled population	A population that forms, disseminates, and applies knowledge in an efficient manner. Education plays a crucial role here, as it is necessary for the acquiring and application of knowledge and technological/scientific advancement.	Georgia citizens and Georgia's agriculture industry, as these comprise the individuals and entities who create, share, and apply knowledge to apply and innovate. Future professionals in the agriculture industry also exist here.
Information and communication technologies (ICT) infrastructure	Infrastructure that facilitates the communication, dissemination, and processing of information and technology. As efficiency of facilitation increases, there is greater communication, productivity, and output.	Infrastructure within Georgia that facilitates the communication, dissemination, and processing of information and technology—e.g., social media, television, Extension, websites, etc.
Innovation system	Systems that involve firms, universities, research centers, think tanks, etc. that use and apply knowledge to create new technology, leading to productivity growth.	The University of Georgia as a research center, as it is an institution with a land-grant mission to apply knowledge and contribute to productivity growth. Students at the university are also found here, as they are learners and researchers that have the potential to contribute to productivity growth as future professionals.

A visual conceptualization of the pillars and their components and contributions on a state level can be seen in Figure 3.1. All pillars contribute to the KE, but they each play a different role in the development of it (MacLeod & Urquiola, 2021). Pillar 1 involves the state government and economy of Georgia, which incentivizes research, innovation, and productivity through funding and investments in various institutions and infrastructures, a viable market economy, and related policies. Pillar 2 involves any professionals within the agriculture industry as well as state citizens (which could include policymakers, consumers, farmers, etc.). Pillar 3 involves the infrastructure available for disseminating and receiving information, which is used among actors within each of the other three pillars. Finally, Pillar 4 involves the university as an educational institution and a research center in which students are trained to be future professionals within the agriculture industry. Pillar 4, which includes students at the university contributes to Pillar 2, which includes the state's agriculture industry, as students become professionals (or part of a skilled and educated population) within the agriculture industry.

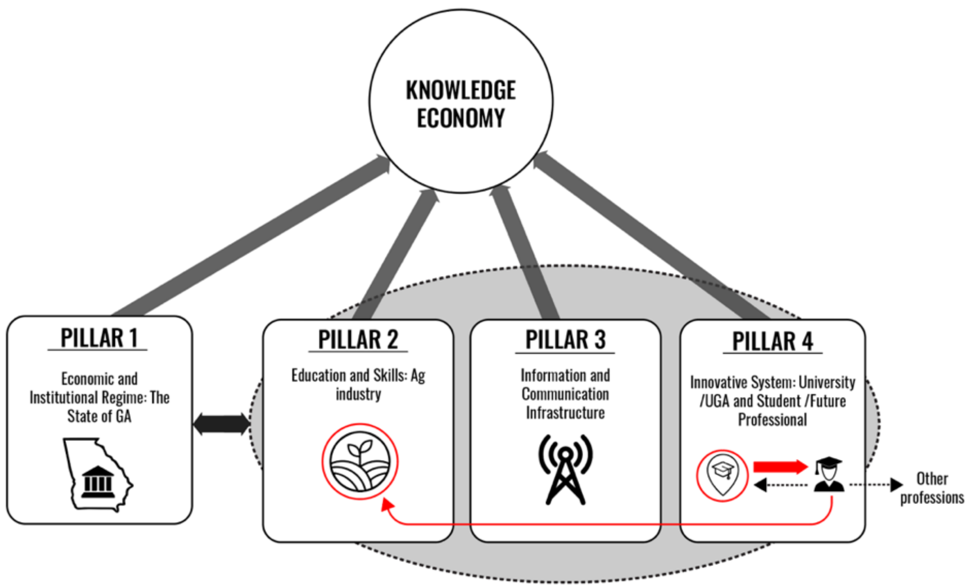

Figure 3.1
The KE Framework Applied to the State Level

A double-sided arrow exists between student/future professional and the university because students don't always join the workforce after graduation—a portion enroll in graduate school and contribute their knowledge and skills back to the university through engaging in research and further knowledge acquisition and development (Li, 2022). Additionally, not all students join the agriculture industry as professionals, even if they were enrolled in degree programs that intend to prepare them for that specific workforce, hence why an arrow extends from the student to other professions.

Focusing more closely on the ICT Infrastructure pillar of the KE, one way in which actors within KE communicate information is through conversation and collaboration (Hadad, 2017; Tiwari, 2022; Unger, 2022). For the present study, professionals within the agriculture industry could share their knowledge regarding science communication skills with academia, thus giving insight into practical, work-based skills to help inform a science communication curriculum at the university level that's balanced in both theory and practice. This process is known as university-industry collaboration (UIC), in which universities consult with industries of interest and engage in discussions regarding what both sides want to incorporate into a curriculum (Erkarslan & Aykul, 2018; Ishengoma & Vaaland, 2016; Nangia & Pramanik, 2011; Spier, 1995).

Curricula that are exemplary results of this process include a teaching resource for undergraduate science communication curriculum development (Mercer-Mapstone & Kuchel, 2017), a co-operative model based on a Plan–Do–Study–Act cycle that was applied in the curriculum design of two courses in welding within a Manufacturing Engineering Master's program (Valiente Bermejo et al., 2022), and a co-designed and co-delivered curriculum focused on enhancing students' data literacy skills for students to succeed in the labor market within the digital era (Taş, 2023).

The UIC framework can be applied to the KE framework at the state level, which can be seen in Figure 3.2. Universities, or more specifically professionals in academia, converse with the agriculture industry, or more specifically professionals within the agriculture industry. Furthermore, the goal of UIC is for engagement to occur in equal proportion between the two actors, thus collaboration is in the center of a communication scale, in which silence (zero collaboration) occurs on one end of the spectrum, and conflict (also zero collaboration) occurs on the other end of the scale. Silence occurs when there is no infrastructure in place for conversation to occur, and conflict occurs when either entity is unwilling to contribute to the conversation in a meaningful or productive manner (Rajalo & Vadi, 2017; Rose et al., 2021; Wright, 2017).

Finally, a curriculum can be overarching and applied across departments and degree programs, or it can be tailored to individual degree programs, something that might be more attractive in terms of effective science communication curriculum (Parrella et al., 2023). Thus, as there is such a wide variety of sectors and professional pathways within the agriculture industry (Weiner, 2003), it's important to gain nuanced perspectives among industry leaders, hence why Q methodology was a suitable methodology to use for this study.

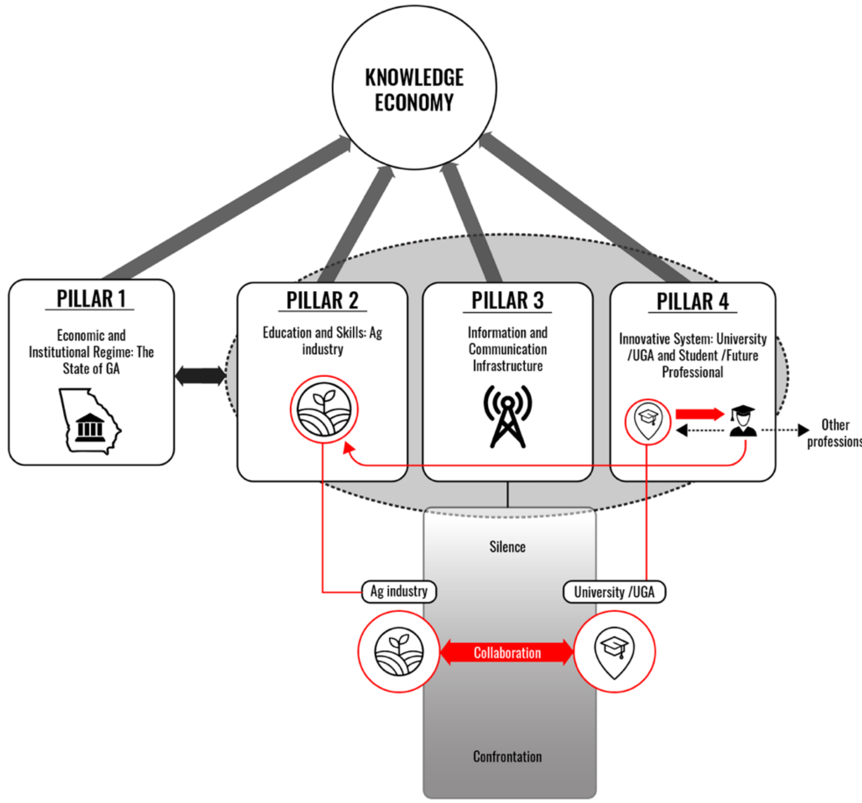

Figure 3.2
The KE Framework Applied to the State Level with UIC

Purpose and Objectives

The purpose of this study was to explore shared and nuanced viewpoints among leaders in Georgia's agricultural industry regarding the importance of various science communication skills within Georgia's agricultural industry. Using a conceptual framework consisting of the pillars of the KE and the addition of the UIC model, the following research objectives guided this study:

1. Describe the sociodemographic characteristics of leaders in Georgia's agricultural industry.

2. Explore Georgia's agricultural industry leaders' perceptions of levels of importance of various skills related to communicating science within Georgia's agricultural industry.
3. Examine how viewpoints are nuanced among various agricultural industry leaders in Georgia regarding the level of importance of various skills related to communicating science within Georgia's agricultural industry.

Methods

General Overview of Q Methodology

Developed by William Stephenson in the 1930s, Q methodology is a methodology that allows for accessing subjective viewpoints via a combination of qualitative and quantitative methods, and it is particularly useful when a certain group of people's viewpoints are considerably important relative to a specific subject matter (Watts & Stenner, 2012). It has also been used in studies with foci similar to the focus of this study, such as professional development format preferences (DeVore-Wedding et al., 2018), industry leader perspectives (Nicholson & Cushman, 2000), and training preferences (Irie et al., 2018). Furthermore, there are already few studies in the literature that examine industry leaders' perceptions of science communication, let alone agriculture industry leaders' perceptions of the importance of science communication skills within the agriculture industry, and they often involve measuring subjective data via methods that don't necessarily capture nuanced perspectives as effectively as Q methodology would, such as Likert-type scales, interviews, or focus groups (Sinclair & Phillips, 2019; Smalley et al., 2016). Therefore, Q methodology is a novel, and potentially promising, methodology for this study.

The method through which Q methodology is practiced is known as the Q-sort, in which selected participants rank several items prepared by the researcher (i.e., statements, images, etc.)

on a given scale involving some subjective dimension (i.e., least agree to most agree, or least prefer to most prefer), allowing for participants to portray their personal viewpoints on a particular issue or topic. Then, after the Q-sorts have been intercorrelated, the researcher conducts a by-person factor analysis of the sorts. This analysis process involves comparing the different sorting patterns among participants through detecting any '...shared modes of engagement, orientations, or forms of understanding…' (Stenner et al., 2000, p. 442). A visualization of all steps involved in conducting a study using Q methodology can be seen in Figure 3.3.

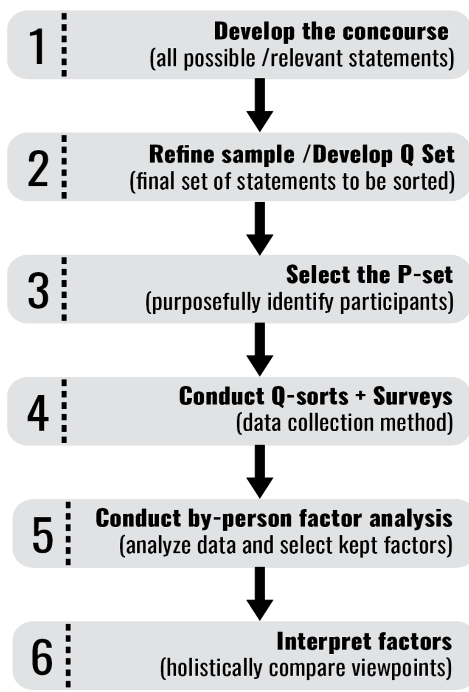

Figure 3.3.
Steps for Conducting a Q Methodology Study

Concourse and Q Set

As previously mentioned, the researcher prepares the items ranked by the participants. This collection of items, known as the Q set, is derived from a larger collection of items, known as the concourse. In the present study, the concourse was developed in an unstructured manner, meaning that the aim wasn't necessarily to represent assumptions or concepts but to reveal all possible positions on a specific variable (Lobinger & Brantner, 2019), by 'harvesting' statements from seven peer-reviewed articles that the researcher and the research committee (which involved a team of professors within the Agricultural Leadership, Education, and Communication department at the University of Georgia) agreed mentioned most, if not all, possible skills that could be associated with science communication within the context of agriculture (Bongomin et al., 2020; Doerfert & Miller, 2006; Kurtzo et al., 2016; Mercer-Mapstone & Kuchel, 2017; Metcalfe, 2019; Oliveira et al., 2021; Shivni et al., 2021). Moreover, the articles involved multiple aspects of communication and included considerations about skills needed in general for future industry trends. Over 100 initial statements were harvested, and then any repeat statements, double-barreled statements, or irrelevant statements were deleted. After three rounds of careful consideration, a total of 39 statements were selected for the final Q set. Grammar of each statement was changed to ensure sentence structure consistency. A chart of the articles and the statements harvested from them can be seen in Table 3.2.

Table 3.2
Articles From Which Q-Set Statements Were Harvested

Article References	Harvested Skill
1. Mercer-Mapstone, L. & Kuchel, L. (2017). Core Skills for Effective Science Communication: A Teaching Resource for Undergraduate Science Education. *International Journal of Science Education, Part B, 7*(2), 181-201.	S08, S09, S22, S23, S03, S07, S30
2. Doerfert, L. D. & Miller, P. R. (2006). What Are Agriculture Industry Professionals Trying to Tell Us? Implications for University-Level Agricultural Communications Curricula. *Journal of Applied Communications, 90*(3).	S13, S20, S36, S11, S17, S27, S28, S32, S18
3. Bongomin, O., Ocen, G. G., Nganyi, E. O., Musinguzi, A., Omara, T. (2020). Exponential Disruptive Technologies and the Required Skills of Industry 4.0. *Journal of Engineering*, (*2020).*	S01, S37, S02, S35, S07, S10, S12, S31
4. Kurtzo, F., Jo Hansen, M., Rucker, K. J., and Edgar, L. D. (2016). Agricultural Communications: Perspectives from the Experts. *Journal of Applied Communications, (100)*1.	S19, S21, S26, S05, S03, S07, S30, S38, S29, S31, S34
5. Metcalfe, J. (2019). Comparing science communication theory with practice: An assessment and critique using Australian data. *Public Understanding of Science*, *28*(4), 382–400.	S04, S05, S14, S39, S06, S15, S24, S33
6. Shivni, R., Cline, C., Newport, M., Yuan, S., and Bergan-Roller, H. E. (2021). Establishing a baseline of science communication skills in an undergraduate environmental science course. *International Journal of STEM Education, 8*(47).	S25, S03, S07, S31
7. Oliveira, Alandeom & Brown, Adam & Carroll, Marissa & Blenkarn, Elizabeth & Austin, Bradley & Bretzlaff, Tiffany. (2021). Developing undergraduate student oral science communication through video reflection. *International Journal of Science Education, Part B*. *11,* 1-12.	S16, S03, S07, S30, S24, S31

Note. Some statements were harvested from multiple articles and are thus listed more than once. Statements can be seen in Table 4.5.

P Set and Procedures

The sample size for Q methodology is recommended to be much smaller than common sample sizes for quantitative studies, as this allows for a more intentional capturing of various viewpoints to enhance quality. Furthermore, the P set is determined once a salience of potentially unique viewpoints is reached (Brown, 1980; McKeown & Thomas, 2013; Watts & Stenner, 2012). Importantly, this approach does not result in generalizable conclusions but instead reveals the different perspectives within a specific group (Brown, 1980). For this study, which received Institutional Review Board (IRB) approval in October 2023, 18 leaders in Georgia's agriculture industry (hereafter referred to as industry leaders) were selected through purposive sampling of past, current, and board members of Advancing Georgia's Leaders in Agriculture and Forestry (AGL).

AGL is a UGA program with a mission to educate, empower, and connect "today's professionals in agriculture, forestry, natural resources, and allied sectors to be dynamic industry leaders (*Advancing Georgia's Leaders in Agriculture and Forestry*, 2023). Members must be nominated to enroll in the program, and nominees must be "actively involved in Georgia's agriculture, forestry, natural resources and/or supporting industries" and "be able to demonstrate leadership experience, [and] work experience…" (Advancing Georgia's Leaders in Agriculture and Forestry, 2023). Moreover, each cohort has roughly 25 individuals "diverse in age, gender, ethnicity, geographic location, professional background, and level of experience" (Advancing Georgia's Leaders in Agriculture and Forestry, 2023). Diverse representation is necessary for both developing more inclusive scientific and technological innovation and science communication (Canfield et al., 2020), as well as capturing nuanced perspectives in a Q study (Brown, 1980).

In October 2023, the AGL Program Director sent out general recruitment emails to the past two cohorts, the current cohort, and the current Board Members. Upon agreeing to participate, 30 AGL members were contacted by the lead researcher via email with instructions on how to participate in the study, which was distributed through a web-based software program known as QMethod Software (qmethodsoftware.com). A total of 18 AGL members completed the study activities between October 2023 and January 2024. To complete the web-based survey, participants were asked to read through all 39 skill statements and place them into three piles according to their initial agreement, neutrality, and disagreement. The participants were then asked to rank the statements on the Q sorting grid from most unimportant (-5) to most important (+5), with neutral (0) in the center of the forced-choice frequency distribution (ex: 'S21: +3). The following prompt guided the participants' sorting decisions: "When considering the skills needed to effectively communicate science within the area/field of Georgia's agriculture industry with which you're engaged as a leader, it's important that employees have the ability to [blank]". Figure 3.4 displays the sorting grid that was used by participants during the Q sorting exercises on qmethodsoftware.com. After completing the Q sort, participants were asked to complete a survey in which they explained their rationale for their sorting processes and decisions as well as provide demographic information.

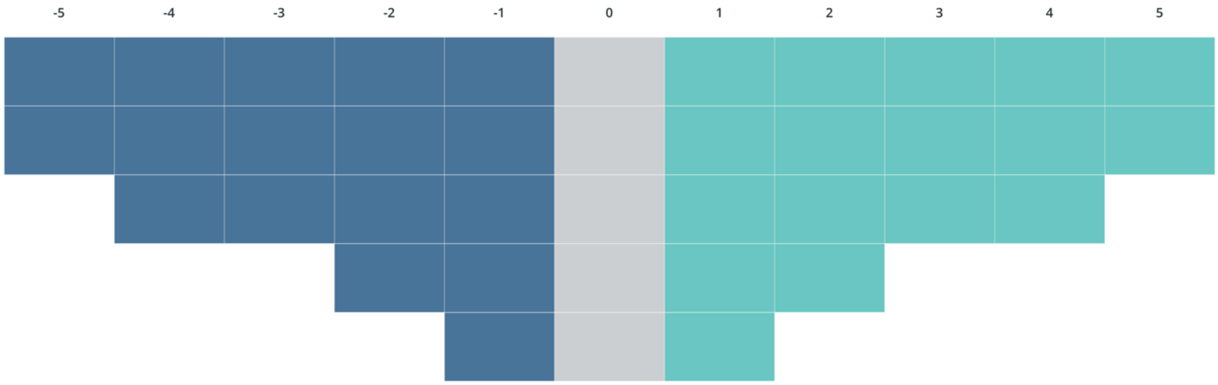

Figure 3.4
Q-sort Distribution Grid

Note. Blocks in the -5 column represent 'most unimportant' skills, and blocks in the +5 column represent 'most important' skills. Rankings vertically have no value. Only rankings horizontally matter during the data analysis process.

Statistical Analysis

Following data collection, data was analyzed in QMethod Software, as it is both a web-based data collection tool and a data analysis tool. An intercorrelation matrix of the participants' Q sorts was constructed to calculate the positive or negative relationships between each of the individual Q sorts. Next, to identify correlations, the matrix was subjected to principal components analysis (PCA) and factor-analyzed on a by-person basis. This process identifies statistically significant factors in which very similar perspectives across Q sorts are grouped into corresponding factors, and eight unrotated factors were initially yielded that accounted for 78.72% of the total variance. These eight unrotated factors are merged Q sorts that represent shared viewpoints, thus forming a single Q sort that best represents each of the merged Q sorts through a weighted average. However, it is recommended to only keep factors with an eigenvalue of 1 or more (Brown, 1980). Therefore, six factors met this criterion.

Crucial to the direction of the study is deciding the number of kept factors for final analysis (McKeown & Thomas, 2013), although there is no objective process for deciding the most appropriate number of factors to keep (Aragao Pereira, 2011). Nonetheless, potential concerns of the suitability of kept factors were considered, and additional measures taken to decide the most appropriate number of kept factors included applying the significance criterion, which means each factor kept for rotation must have two or more significant Q sort loadings (Watts & Stenner, 2012). A real-world reflection of the factors kept for analysis was also considered (Watts & Stenner, 2012), such as considering the weight of importance of various participants' perspectives. After further consideration of the factors, four meaningful factors were extracted for varimax rotation. 16 of the 18 Q sorts loaded significantly onto one of these four factors, explaining 55.12% of the total study variance. As the minimum threshold for a loading value is at 0.41 (2.58 x 1/√ (number of statements) = 2.58 x 1/√39) (Stenner & Watts, 2012), the remaining two participants did not load significantly onto a single factor because they shared many of the same viewpoints within factors one, two, and three. The views of the two participants that did not load significantly onto a single factor were captured by the already existing factors, so these two corresponding Q sorts were not included for further analysis. However, the correlations between each identified factor were relatively low, meaning the viewpoints within each factor are distinct from those in other factors. Factor correlations can be seen in Table 3.3.

Table 3.3

Correlations Between Each Identified Factor

	Factor 1	Factor 2	Factor 3	Factor 4
Factor 1	1.00	0.3291	0.3858	0.0727
Factor 2	0.3291	1.00	0.1263	0.1859
Factor 3	0.3858	0.1263	1.00	0.0446
Factor 4	0.0727	0.1859	0.0446	1.00

Note. A relatively low correlation between each of the factors exceeds the study's significance level of 0.41, which reveals that viewpoints among factors are distinct. Each factor represents the common viewpoints among a group of Q sorts that were ranked in very similar manners.

Lastly, a qualitative picture of the individual perspectives within each of the extracted factors was applied to the data in this study using the crib sheet method, which systematically and holistically examines the results of this study through revealing patterns and unique viewpoints within each of the identified factors (Watts & Stenner, 2012). The crib sheet method involves organizing statements based on their relative rankings in comparison to the other factors, which is done by placing the statements in four groups: the highest ranked statements in each factor, the lowest ranked statements in each factor, statements ranked higher in one factor compared to any other factor, and statements ranked lower in one factor compared to any other factor (Watts & Stenner, 2012). This method also requires the consideration of other potentially influential data, such as demographic data of the participants and post-sort reflections. It is in essence a big-picture and simultaneously detail-oriented manner of exploring Q methodology data (Watts & Stenner, 2012).

Results

As purposive sampling measures were used to ensure potentially diverse perspectives regarding the research question, the characteristics of the participants represented in this sample achieved the goal of diversification. Industry leaders in this study were 25 to 69 years of age, half were male (50%) and half were female (50%), and they engaged with a variety of leadership roles, from CEOs (18.75%) to General Managers (31.25%) to PR Managers (12.5%) at various agricultural companies. Company sizes ranged from 0-15 employees (31.25%) to 100+ employees (43.75%), and the companies' foci varied as well, from support and services to production to research. Most of the companies' foci included more than one area (i.e., research, production, and support and services). Moreover, most of the companies worked with multiple of Georgia's top agricultural commodities (i.e., broilers, peanuts, cotton, turf, greenhouse products, dairy, beef, blueberries, pecans, turf, and timber) (*About Georgia Ag*, 2023), while some factors included industry leaders who worked directly with energy (F4; F3). Participants indicated that all the associated companies had been part of the agriculture industry in Georgia for more than 10 years. Despite some differences between the characteristics of leaders and their associated companies within each study factor, no statistical tests were used for this data set. Demographic data is presented in Table 3.4 and is solely meant to provide some descriptive information for this study.

Table 3.4
Demographic Characteristics of Study Participants in Each Identified Factor

	F1	F2	F3	F4	Total
Number of industry leaders	6	4	3	3	16
Age range (based on brackets)	35-54	25-65+	35-44	25-44	25-65+
25-34	0	1	0	1	2 (12.5%)
35-44	3	1	3	2	9 (56.25%)
45-54	3	1	0	0	4 (25%)
55-64	0	0	0	0	0 (0%)
65+	0	1	0	0	1 (6.25%)
Gender (male)	2	1	2	3	8 (50%)
Gender (female)	4	3	1	0	8 (50%)
Race/Ethnicity					
Caucasian	6	3	3	3	15 (93.75%)
Hispanic	0	1	0	0	1 (6.25%)
AGL Member Type					

Previous Class Member	6	2	0	0	8 (50%)
Current Class Member	0	2	2	1	5 (31.25%)
Board Member	0	0	1	2	3 (18.75%)
Length of Time Industry Leader has Lived in Georgia					
1-5 years	2	0	2	1	5 (31.25%)
6-10 years	0	2	0	1	3 (18.75%)
10+ years	4	2	1	1	8 (50%)
Industry Leader Position at Associated Company					
General Manager	2	0	2	1	5 (31.25%)
CEO	2	0	0	1	3 (18.75%)
Executive Director	0	2	0	0	2 (12.5%)
Communications Coordinator	1	0	0	0	1 (6.25%)
Account Manager	1	0	0	0	1 (6.25%)
Veterinarian	0	1	0	0	1 (6.25%)
Sales Territory Manager	0	1	0	0	1 (6.25%)
PR Manager	0	0	1	1	2 (12.5%)
Number of Employees at Associated Company					
0-15 employees	3	1	0	1	5 (31.25%)
16-50 employees	0	1	2	1	4 (25%)
51-100 employees	1	0	0	0	1 (6.25%)
100+ employees	3	2	1	1	7 (43.75%)

Note. “Associated Company” refers to the agriculture company in Georgia at which an industry leader has held a position.

Respective statement scores denote the factor scores of the Q sorts for the four extracted factors in Table 3.5. The table also includes each statement ranking within each factor, distinguished statements in each factor that were significant and distinguish one factor from another, and consensus statements that show which statements were ranked most similarly among all four factors (shown in brackets).

Table 3.5

Factor Scores for All Skill Statements by Each Identified Factor

No.	Statements	F1	F2	F3	F4
1.	Think logically and analytically	0	0	2	4
2.	[Adapt to ever-changing communication technologies]	-2	0	-1	-3
3.	Use style elements appropriate for the mode of communication (e.g., humor, analogy, metaphors, body language, diagrams, etc.)	-1	2*	0	-1
4.	Bring together people from different disciplines or areas to work together on a communication-related goal/project	1	0	3*	-2*
5.	Participate with the public in policy making	-2	-3	1**	4**
6.	Persuade a target audience about the benefits of science	-1	-1	-1	4**
7.	Use language that is appropriate for the target audience	4	3	1*	-2
8.	Evaluate communication outcomes and apply knowledge to future communication efforts	3*	-1	-4**	0**
9.	Identify a suitable target audience for a specific message	0	4**	-4**	1
10	Use accurate and meaningful statistics when communicating science-related information	4	-1	5	1
11.	Work under the constraints of communication-related budgets	4**	-5	0**	-4
12.	[Use digital media for communicating information (e.g., social media, websites, blogs, digital photos, podcasts, etc.)]	1	1	0	-2
13.	Strategically plan communication-related activities	5*	2	-2*	2
14.	Engage citizens democratically in science and technology issues	-4	-4	1	2
15.	Use traditional means of mass media to communicate information (e.g., print, TV, radio)	-1	-5**	0	-2
16.	Exhibit self-confidence when communicating science	1	1	1	5**
17.	Respond quickly during communication-related activities	-1	1*	-1	-5**
18.	Disseminate the same information across converging media (e.g., among different media platforms and technologies)	1*	-3	-2	-1
19.	Conduct research for communication-related purposes (e.g., conduct a survey on a specific audience to better understand their feelings/values/etc. about a specific science topic)	-2*	-4	4**	-5
20.	Identify and consider stakeholders' diverse communication needs, wants, and preferences	2	3	2	-1**
21.	Anticipate future shifts and trends in communications	-2	-4	-3	-1
22.	Identify the purpose and intended outcome of the communication	2	3	-3**	5**
23.	Engage in two-way dialogue with a target audience	-3	-1	-2	3**

24.	Verbally communicate information with a target audience (e.g., give a speech, presentation)	-1	0	4	2
25.	Plan and execute remote communication-related projects (a remote project involves professionals working from different physical locations on a unified project)	-3	1*	-1	-3
26.	Incorporate feelings with facts	-4*	2*	-5*	0*
27.	Navigate activist pressure related to science issues/topics	-4	-1*	-5	1*
28.	[Appear trustworthy and credible during any communication-related activity]	3	5	5	3
29.	Communicate through writing with the target audience (e.g., articles, blog posts, social media posts, etc.)	0	0	0*	-3
30.	Use stories to communicate information	0**	4	3	3
31.	Communicate visually with a target audience (e.g., graphs, infographics, videos, pictures, etc.)	2	4	3	-3**
32.	[Quickly disseminate information regarding risk and crisis communication]	0	-2	0	-1
33.	[Put up a display/exhibit to communicate information]	-5	-2	-4	-4
34.	Communicate through electronic communications to a target audience (e.g., email, e-newsletters, etc.)	1	2	-2**	1
35.	Quickly solve communication-related problems (such as correcting incorrect information that was accidentally shared, mitigating unexpected backlash from audiences, etc.)	3	-2	4	0
36.	Identify and use a diverse array of digital technologies used by target audiences	-3**	1	-1	2
37.	Work well with teams	2**	-3**	1	0
38.	Create messages that are short, concise, and clear	5	5	2	1
39.	Debate scientific/technological issues	-5*	-2	2**	-4

Note. The four factors (represented in this table as F1, F2, F3, and F4) were analyzed by examining which statements most represented similar and different views between each group. To indicate significance levels, distinguishing statements are indicated with $*p < 0.05$ and $**p < 0.01$. Consensus statements are bracketed.

Defining and Describing Each Factor

Using the previously mentioned crib sheet method to analyze the data, four unique factors were representative of the viewpoints captured through the present study. Each factor represents a set of skills that was considered most important by the participants within each factor and is described as a specific skillset. Factor 1, Strategize on a Budget, includes industry leaders who are strategically driven and believe in the power of evaluation, as well as communicating in a to-the-point manner while appearing trustworthy and credible. They also feel strongly about working within budget constraints. Factor 2, Empathize with Audiences and Leverage Communication Technology, includes industry leaders who place the most emphasis on understanding target audiences and tailoring messages to their needs through up-to-date and emergent technologies. Working within budget constraints is not much of a concern for them. Factor 3, Exude Credibility and Communicate Quickly, include industry leaders who deem skills related to appearing credible and trustworthy, communicating efficiently and quickly, and communicating with an intended target audience in mind as most important. They also value traditional means of communication and teamwork, as well as an understanding and use of digital media. Finally, Factor 4, Exude Confidence and Engage Audiences, believe exuding a sense of confidence when communicating science is most important, and they also value participatory policy making and two-way communication more so than one-sided communication efforts.

Each factor will now be described in greater detail through the consideration of the shared viewpoints among participants within each factor as well as the shared and nuanced viewpoints of participants within one factor compared to those in other factors. Also, each factor will be discussed in terms of its demographics, highest and relatively higher ranked scores, and lowest and relatively lower ranked scores.

Strategize on a Budget (F1)

Demographics (F1)

The 6 participants who loaded significantly onto Factor 1 range in age from 35 to 54 years and include two general managers, two CEOs, one communications coordinator, and one account manager. Two work directly with peanuts, one works with greenhouse and ornamental commodities, and three work with most or all of Georgia's top agricultural commodities. Lastly, the purposes of every organization associated with each participant involves management, production, outreach, research, services and support, and education.

Highest and Higher Ranked Skills (F1)

The participants in this factor believe the most important aspect of effective science communication is developing messages that are short, concise, and clear, while activities surrounding the development and dissemination of the message should be strategically planned (S38: +5; S13: +5). More so than in the other three factors, these participants believe strategic planning involves identifying and using language that is appropriate for the target audience (S07: +4) while also evaluating communication outcomes and applying that knowledge to future communication activities (S08: +3). "Communications staff… need to be able to plan out communication strategies and be able to evaluate the programs they have in place to determine how to move forward in the future" (Participant 3). They also believe, like the beliefs of the other factors, that appearing trustworthy and credible during any communication-related activity (S28: +3), considering stakeholders diverse communication needs, wants, and preferences (S20: +2) and using accurate and meaningful statistics when communicating science-related information (S10: +4) are essential skills to have within their respective agriculture sectors in Georgia. Therefore, participants in Factor 1 perceive skills related to message creation and evaluation of message effectiveness as the most important skills for future professionals to have regarding science communication within their agricultural sectors.

On a similar note, they also believe that being able to construct these types of messages and communication activities and evaluations within the constraints of communication-related budgets is an essential skill to have (S11: +4). "[I] believe it is important going into a project to have a plan and be able to work within a specified budget" (Participant 2). "…those working in communication programs at commodity organizations or non-profit companies have to consider their overall budget when making decisions regarding communication projects and how they're going to be implemented" (Participant 3). They believe working well with teams could support this goal (S37: +2), but they don't believe planning and executing remote communication-related projects (i.e., working with professionals from different physical locations on a unified project) is an essential skill to have (S25: -3). Furthermore, they believe being able to use digital and converging media to disseminate information (S12: +1; S18: +1) is key to creating timely and consistent messages for multiple target audiences without using too many resources. "We expect our communications to be trustworthy and timely for our stakeholders and efficient and effective from the business perspective" (Participant 4).

Additionally, participants in Strategize on a Budget believe communicating through writing (S29: 0) and visuals (S31: +2) with a target audience are more important skills to have than communicating orally with a target audience (24: -1). Thus, they believe using articles, blog posts, social media posts, etc. are more effective than using presentations or speeches when communicating science, and they believe graphs, infographics, etc. are useful tools for communicating science. This could be because writing and visuals are some of the most accessible means of acquiring information in a quick and digestible manner (Guo et al., 2020).

Lowest and Lower Ranked Skills (F1)

Participants in this factor believe using stories to communicate information (S30: 0) is a less important skill than does any other factor, but they still deem it neutrally important. This could be because they believe sharing short and concise messages are key to effective science communication, and using stories could result in messages that are too long for audiences to pay attention to or digest. Similarly, participants in Strategize on a Budget believe engaging in two-way dialogue about science with a target audience (S23: -3) and engaging citizens democratically in science and technology issues (S14: -4) are less important skills regarding science communication compared to the viewpoints in other factors. In other words, they believe getting short, understandable messages out to a wide variety of audiences through primarily digital media, without much co-creation of knowledge, is key to effectively communicating science within the agriculture industry. “The difficulty lies in the time it takes to explain certain issues, you have lost the audience and typically the argument. Developing quick, simple, easy-to-understand examples are most effective” (Participant 2). This further supports the idea that participants in Strategize on a Budget deem putting up a display or exhibit to communicate information (S33: -5) and debating scientific and technological issues (S39: -5) the most unimportant skills for future professionals to have in terms of communicating science, as they are not the most efficient or straightforward ways to communicate information.

Empathize with Audiences and Leverage Communication Technology (F2)

Demographics (F2)

Factor 2 consists of participants with the broadest range of ages, from 25 to over 65 years of age. Two executive directors, one veterinarian and one sales territory manager are included. Two participants work directly with timber and conservation/land management, one works directly with poultry science, and one works directly with all row crops and specialty commodities. The organizations associated with these participants are focused on research, production, services and support, and communications.

Highest and Higher Ranked Skills (F2)

Identical to participants in Strategize on a Budget, participants in Factor 2 believe developing messages that are short, concise, and clear is essential to effective science communication (S38: +5). However, participants in this factor place more importance on appearing trustworthy and credible during any communication-related activity (S28: +5). They also place more emphasis than does any other factor on the importance of identifying a suitable target audience for a specific message (S09: +4), as well as considering stakeholders' diverse communication needs, wants, and preferences (S20: +3). Thus, participants in this factor are more concerned than those in other factors about audience segmentation and the perceptions of the persons communicating science-related information. Furthermore, they are more concerned than those in any other factor about the content and method of the message matching with, or relating to, the audience. For example, they believe using stories to communicate information (S30: +4), using style elements appropriate for the mode of communication (S03: +2), and using visuals (S31: +4) are ways in which an intended audience can effectively receive, understand, and apply a message. They also believe incorporating feelings with facts is important (S26: +2), more so than do other factors. "I believe the important skills relate to people's needs and emotions. We need to meet them where they are to get the message across clearly" (Participant 7).

Furthermore, participants in this factor believe communicating through electronic communications to a target audience (S34: +2), planning and executing remote communication-related projects (S25: +1), using digital media for communicating information (S12: 0), and adapting to ever-changing communication technologies (S02: +1) are all important to science communication efforts, more so than do other factors, thus suggesting that participants in Factor

2 strongly value staying updated in regard to every-changing technologies and platforms. To further support this, they believe using traditional means of mass media to communicate information (e.g., print, TV, radio) is the most unimportant skill to have (S15: -5). Ironically, these participants also deem anticipating future shifts and trends in communications as a relatively unimportant skill (S21: -4). Nonetheless, participants in this factor appear to value the skills of expressing empathy and credibility, as well as using more up-to-date communication technologies.

Lowest and Lower Ranked Skills (F2)

Interestingly, participants in Empathize with Audiences and Leverage Communication Technology don't value the skill of using accurate and meaningful statistics when communicating science-related information (S10: -1) or working well with teams (S31: -3) as much as Factors 1, 2, or 4 do. Also, compared to the other factors, they place the least amount of emphasis on engaging target audiences through participatory policy making (S05: -3) and engaging citizens democratically in science and technology issues (S14: -4). Furthermore, they believe that the most important skills regarding effective science communication do not necessarily involve engaging in time-consuming processes but also don't involve quickly disseminating information (S32: -2; S35: -2). Overall, they're seeking professionals who can strike a balance between methodically crafting messages based off audience characteristics and feelings and disseminating messages through up-to-date and emergent technologies and platforms, thus reaching people in personal and meaningful ways. "My experience is the personal touch of communication is becoming a lost art. Delivering a clear message with the personal feeling has always been the best way to convey the message" (Participant 8). Lastly, in complete contradiction to the viewpoint of those in Strategy on a Budget, participants in

Empathize with Audiences and Leverage Communication Technology believe working within the constraints of communication-related budgets (S11: -5) is one of the most unimportant skills to have, thus indicating that they're open to spending more resources on communication-related activities so long as they result in thoughtfully crafted and accessibly delivered messages.

Exude Credibility and Communicate Quickly (F3)

Demographics (F3)

Participants in Factor 3 fall between the age of 35 and 44 and include two general managers and one public relations manager. One works directly with cotton, one works directly with energy, and one works with most or all of Georgia's top agricultural commodities.

Highest and Higher Ranked Skills (F3)

The top ranked items for Factor 3, known as Exude Credibility and Communicate Quickly, include using accurate and meaningful statistics when communicating science-related information and appearing credible and trustworthy during any communication-related activity (S10: +5; S28: +5). Thus, participants in Factor 3 value skills that involve understanding statistics and being able to use them in relevant contexts while also appearing valid and authentic in a communication-related context. Factor 3 participants also emphasize more so than do other factors the importance of conducting research for communication-related purposes (e.g., conducting a survey on a specific audience to better understand their feelings/values/etc. about a specific science topic) (S19: +4). Therefore, these participants believe data analytical skills, such as being able to collect, analyze, and effectively communicate data, are important in the context of communicating science within their sectors of the agriculture industry in Georgia.

Moreover, these participants believe quickly disseminating information and solving communication-related problems is important (S32: 0; S35: +4), yet they also believe using more traditional communications methods is effective in terms of communicating science, such as orally communicating information with a target audience (S24: +4) and using traditional means of mass media (e.g., TV, print, radio, etc.) (S15: 0). “I think the basics of… communication skills still apply today like they always have” (Participant 11). To further support this, they believe using electronic communications (e.g., e-mail, e-newsletters, etc.) to communicate information to a target audience (S34: -2) isn’t as important as other factors believe it to be. Also, they believe more so than any other factor that bringing people together from different disciplines or areas to work together on a communication-related project (S04: +3) is an important skill to have. “In order to have complete and credible information to communicate, it is very important to be able to bring together different people for a common goal. I feel like academia often focuses so much on information and not how to apply it to working in the real world and how to work with different people. [People skills] are a huge part of engaging many parties to land on the right message” (Participant 13). They also believe much more so than does any other factor that effectively debating scientific and technological issues is a necessary skill (S39: +2). Thus, participants in Factor 3 seem to value exhibiting credibility and confidence and leaning on traditional means of communication when communicating science-related information.

Lowest and Lower Ranked Skills (F3)

Like Factors 1 and 2, participants in Exude Credibility and Communicate Quickly don’t believe persuading a target audience about the benefits of science is the most important skill to have (S06: -1). However, in comparison to the viewpoints of all the other factors, the participants in Factor 3 don’t place as much importance on strategically communicating or evaluating the outcomes of communication-related activities (S13: -2; S22: -3; S09: -4; S08: -4). Additionally, they believe navigating activist pressure related to science issues and topics (S27: -5) and incorporating feelings with facts (S26: -5) are the most unimportant skills to have regarding science communication within the agriculture industry. “I don’t think you’re going to change the mind of an activist in a debate. They need to be taken into the field and shown [agriculture]” (Participant 12). “I feel like incorporating feelings with facts was least important because it’s really a communications practitioner’s job to present facts and let the audience decide how they feel” (Participant 13). Nonetheless, like participants in Strategize on a Budget and Empathize with Audiences and Leverage Communication Technology, participants in Exude Credibility and Communicate Quickly still highly value (relatively speaking) considering stakeholders’ diverse communication needs, wants, and preferences (S20: +2), creating messages that are short, concise, and clear (S38: +2), and using language that is appropriate for the target audience (S07: +1). Overall, these participants believe appearing credible and trustworthy through quickly and practically disseminating information via both traditional and digital means of media are the most important skills to have regarding science communication.

Exude Confidence and Engage Audiences (F4)

Demographics (F4)

Finally, the three participants in Factor 4 fall between the age of 25 and 44 and consist of one CEO, one public relations manager, and one general manager. One works directly with cotton, one works directly with energy, and one works with most or all of Georgia’s top agricultural commodities. The purposes of the companies associated with these participants include primarily communications and services and support.

Highest and Higher Ranked Skills (F4)

Participants in Factor 4, known as Exude Confidence and Engage Audiences, believe that exhibiting self-confidence when communicating science is the most important skill to have (S16:

+5). They ranked this statement higher than did any of the other factors. Along the same line, they value appearing trustworthy and credible during any communication-related activity (S28: +3), like the viewpoint of the participants in Exude Credibility and Communicating Quickly. They also believe that identifying the purpose and intended outcome of the communication is essential to effective science communication (S22: +5). Thus, they value strategy and intentionality, along with being fully prepared and knowledgeable about a topic or issue when communicating science-related messages. "…A specific message with credible information reigns supreme" (Participant 16).

Importantly, participants in Factor 4, more so than those in any other factor, strongly value skills related to engaging the public in participatory policy making and two-way communication-related activities (S05: +4; S23: +3; S14: +2). They also believe navigating activist pressure related to science issues and topics (S14: +2), as well as persuading a target audience about the benefits of science (S06: +4), are more important than do other factors. Thus, they are more likely to value the skill of persuasion and being able to deal with situations in which there is confrontation or competing ideas surrounding a specific science issue or topic. This may be why they believe thinking logically and analytically (S01: +4) is more important than do other factors, as this skill allows for more effective persuasion and problem solving.

Additionally, participants in Factor 4 believe using stories to communicate information is important (S30: +3), as storytelling can make for an effective persuasion tool. However, they ranked the skill of incorporating feelings with facts lower than any other factor did (S26: -1), which is commonly done through storytelling. "For years, we have been saying 'we just need to tell the story'. Our story is great, but feelings can't sustain long term results" (Participant 16). Thus, participants in Exude Confidence and Engage Audiences are weary of storytelling tactics achieving long-term communication-related goals but believe they may be effective for achieving short-term goals.

Lowest and Lower Ranked Skills (F4)

Participants in Factor 4 believe that skills related to the methods of crafting messages (S03: -1; S07: -2; S31: -3) aren't as important compared to the viewpoints of other factors. Along the same line, they believe using various types of media (S12: -2; S02: -3; S15: -2) isn't as important as being able to identify an intended outcome of a message. However, they believe more so than does any other factor that identifying and using a diverse array of digital technologies is important (S36: +2), indicating that, like the viewpoint of participants in Empathize with Audiences and Leverage Communication Technology, they value an understanding of and ability to apply digital technologies in the context of science communication.

Lastly, participants in Factor 4 place the least amount of emphasis on conducting research for communication-related purposes (S19: -5), indicating that they believe developing a message with purpose doesn't involve tailoring the message to appeal to a target audience but rather involves considering what point the message needs to convey to a variety of audiences. "…we must create effective communicators to get our message to a broad audience" (Participant 15). Furthermore, like the participants in Empathize with Audiences and Leverage Communication Technology, and opposite of the participants in Strategize on a Budget, working within the constraints of a communication-related budget is not a very prioritized skill (S11: -4). Additionally, this factor believes responding quickly during communication-related activities is the most unimportant skill (S17: -5), which is further supported by their relatively low rankings of other skills regarding quickly disseminating information (S32: -1; S35: 0). Overall, Confident and Purposeful Engagers value strong intentionality in terms of message development, convincing target audiences about the benefits, values, and facts surrounding science-related information, and remaining trustworthy, credible, and confident while conveying various messages through engaging activities. This might be why they don't value conducting communication-related research (S19: -5), as the knowledge-sharing and growth occurs naturally and synergistically though participatory means of communication.

Shared Viewpoints Among All Factors

While many of the viewpoints within each factor are distinct from one another, there are a few that are salient among all four factors. For instance, every factor deems appearing credible and trustworthy during any communication-related activity (S28) as relatively more important than most other skills. Additionally, every factor considers using digital media for communicating information (e.g., social media, websites, blogs, digital photos, podcasts, etc.) as only slightly important in comparison to other skills (S12). "As the general public relies less and less on traditional media and the speed at which information is disseminated every day, it is important for communicators to ensure the information they are disseminating is credible and accurate. Sloppy and inaccurate information causes much harm that is difficult to come back from" (Participant 13). Thus, participants within each factor believe that conveying a reputation and message that is honest, trustworthy, credible, and accurate is key to effectively sharing science-related information to target audiences. In other words, while using digital media for communicating information is necessary in today's digital era (Rahmatullah et al., 2022), knowing how to use it in general is not as important as first knowing how to appear credible and trustworthy while using it. Overall, all four factors value conveying credibility and accurate information over most other communication-related aspects when it comes to communicating science within their respective agricultural sectors.

Furthermore, all factors agreed that putting up a display or exhibit to communicate information is a relatively unimportant skill to have (S33). “Some of these items seem ‘old-fashioned’ given new media platforms” (Participant 5). While each factor varied in viewpoints regarding the use of traditional versus more up-to-date communication tools and technologies, every factor shared the belief that being able to use displays and exhibits is not essential to effective science communication, although it could be useful in certain scenarios. “I think some [skills] are not actually neutral, but scenario dependent” (Participant 6). Furthermore, many of the participants among all four factors mentioned how they think certain skills would be more necessary for professionals in other roles to have. “The skills with the lesser rankings are the skills that while are necessary in our field, are those skills that are used most often by our communications staff and are not skills that are required in the day-to-day activities of the people in my particular role. Therefore, when hiring for an employee or open role similar to mine, those skills are not as necessary in the day-to-day execution of my role” (Participant 10). “The skills listed in this section are important in our agricultural sector, but they are high-value skills for other roles within our organization” (Participant 4). “The role of the communications staff is not to debate the scientific issues but rather to report and disseminate the information to the stakeholders” (Participant 3). Thus, all skills may be necessary depending on the role a professional has within the agriculture sector, but there are nonetheless some overarching skillsets that consist of skills that rank the highest in importance among each factor.

Finally, every factor strongly believes that science communication skills are playing and will continue to play an important role in the advancement of the agriculture industry in Georgia.

"With the rise in technology use and the challenge of feeding and clothing a growing global population, these skillsets will be vital to communicating with consumers and stakeholders alike" (Participant 1). More specifically, participants among all four factors believe that people are becoming more and more removed from agricultural systems and practices, which is why communicating effectively about these systems and practices is so essential to the sustainability of the agriculture industry. "As more and more people are removed from the farm, the basic understanding of why things happen the way they do are changed. Also, the various multi-media platforms continue to spread false information regarding food and the way food labels are created now adds to a level of fear and misunderstanding among consumers…" (Participant 3). "It will become increasingly difficult to accurately and adequately communicate with those outside of agricultural and environmental sciences…I have witnessed firsthand highly intelligent people believing some of the misinformation because they do not have any experience with agriculture, or any idea what it actually takes to feed, cloth, and house ourselves while protecting the environment in which we all live" (Participant 4). "The distance and understanding between the rural and inner cities are growing. It will be important for our industry to lead the communication effort" (Participant 11). Thus, all four factors agree that many, if not all, of the skills and skillsets discussed in this study are invaluable to an ever-changing agricultural, scientific, and communications landscape.

Discussion, Recommendations, and Conclusion

Q methodology was used in this study to provide detailed and nuanced insights into how industry leaders view the importance of various science communication skills and reveal the most prominent factors influencing industry leaders' perceptions of science communication within the agriculture industry. In the present study, four general viewpoints were defined and described to exemplify the perspectives of leaders in Georgia's agriculture industry across various roles and sectors. Importantly, the results of this study are only directly applicable to the participants and the sectors they represent, but the results are nonetheless meant to inform a detailed illustration of the attitudes and perceptions that this population carries toward various science communication skills. Through exploring these attitudes and perceptions depicted via the diverse viewpoints captured in this study, we aim to discuss how these findings can both inform and contribute to more effective science communication within the agriculture industry, as well as contribute to the development of and enhance existing science communication curricula at the university level.

The depictions of the four factors reiterate the findings of previous studies in that many professionals believe conveying trustworthiness and credibility is the utmost important aspect of effective science communication (Intemann, 2023), and much of the scientific community's approach to public communication has traditionally been built on an assumption that scientifically accurate information is the main driver behind inspiring greater trust in and support for science (Bauer et al., 2007). All four factors strongly value appearing credible and trustworthy during any communication-related activity, and participants in Strategize on a Budget and Empathize and Communicating Quickly especially value using accurate and meaningful statistics in communication efforts. Moreover, participants in all four factors believe creating short, concise, and clear messages is an important skill to have in terms of effectively communicating science, which aligns with findings from previous studies (Besley et al., 2016; Noar & Austin, 2020). Using language that's appropriate for the target audience, such as limiting the amount of scientific jargon in a social media post, can help messages be short, concise, and clear (Besley et al., 2016). However, it's arguable that messages that are too simplistic may decrease trust, as different audiences commonly have different values and circumstances that might not be captured in the message, thus making them feel as though they're being 'overlooked' by scientists (Noar & Austin, 2020). This may be why strategic communication is highly valued among most of the factors, as understanding the values, interests, preferences, and situations of various audiences is essential when tailoring the same message to a wide array of audiences (Goldenberg, 2021).

Additionally, Factors 1, 2, and 3 don't prioritize co-creating knowledge with the public. For example, participants in Strategize on a Budget and Empathize and Communicate Quickly strongly value strategically developing messages for intended target audiences, but they place much less value on engaging in two-way dialogue about science with a target audience and engaging citizens democratically in science and technology issues. In other words, they believe it's necessary to understand the preferences of an identified audience, but they believe it's more important to create messages and disseminate information in a one-way manner (e.g., from an expert to a citizen).

This approach aligns with the "knowledge deficit model", in which it's assumed that the scientist knows best (has the most accurate information) and needs to fill the knowledge gap for the public, who presumably knows little; however, scientists may need to consider communication efforts and objectives that transcend simply transmitting factual knowledge about science to various audiences (Besley et al., 2018). Professionals pursuing knowledge building, as opposed to knowledge sharing, along with identifying and applying useful engagement strategies to foster dialogues between themselves and the public could be more effective in terms of gaining and maintaining buy-in from various stakeholders (Besley et al., 2016; Yuan et al., 2017). A viewpoint that's more in alignment with this argument is that of the participants in Exude Confidence and Engage Audiences, as they place the most emphasis on engaging with various stakeholders through participatory policy making, two-way communication, and citizen-oriented democracy regarding scientific and technological issues. This could be because the three participants who make up the factor of Exude Confidence and Engage Audiences have leadership roles that directly involve communications and/or policy making—they must listen and respond to the public's perspectives often.

However, there are a fair number of individuals in other factors that hold similar roles within similar organizations. Therefore, regardless of role, organization type, or agricultural commodity, industry leaders in Georgia's agriculture industry are primarily concerned with discovering future professionals who can develop effective science-related messages *for* audiences rather than *with* audiences. This is not pointed out as a criticism but rather as an observation regarding what industry leaders believe to be the most effective practices versus what academic theories posit to be the most effective practices in terms of communicating science.

Additionally, theory isn't always fully in alignment with practice, and vice versa (Arteaga et al., 2023; Metcalfe, 2019). While many scholars have argued that the dialogue model of communication is the most effective model for communicating science (Metcalfe, 2019; Reincke et al., 2020), it does not come without its cons (Brossard & Lewenstein, 2009). For instance, the Lay Expertise Model, in which the public's knowledge (e.g., indigenous knowledge of sustainable farming) informs and influences knowledge that's acquired through science-oriented institutions, can be criticized for not adequately considering or giving sufficient credit to the scientific soundness and rigor of, for example, a research institution. Similarly, democratically engaging the public on scientific and technological issues can be criticized for how its aims involve addressing politics rather than increasing public understanding (Brossard & Lewenstein, 2009). Nonetheless, participants' preferences for one-way communication relates to the KE framework in that many communities and groups are underrepresented in KEs, as knowledge is often shared with only the people who can adequately access it (Berkes & Gaetani, 2023; Unger, 2022). For example, many rural communities don't have equitable access to computer technologies or broadband, thus they may be less likely than urban communities to receive digital communications (e.g., an e-newsletter) from an agricultural company discussing a new scientific issue (Reddick et al., 2020). Moreover, science-oriented institutions often overlook the feelings, values, and knowledge bases of underrepresented audiences and thus rarely tailor messages for them, co-create knowledge with them, and overall, include them in science communication efforts (Canfield et al., 2020; Judd & McKinnon, 2021).

However, if scientists and other professionals within the agriculture industry did begin placing more value on engaging underrepresented audiences, there could be more opportunity for an increase in knowledge sharing and building, potentially resulting in new scientific and technological innovations and possibly even new agricultural sectors and industries. In other words, training professionals to be more cognizant of inclusivity and engage in more innovative science communication could allow for the agriculture industry to tap into unexplored areas of Georgia's KE. Examples of projects and activities that exemplify this concept include the Biota Project (Cheng et al., 2018) and various citizen science activities (Ebitu et al., 2021; Mahajan et al., 2020).

Yet, there are barriers to innovative science communication efforts, one of which is budget constraints (Entradas et al., 2020). While the effectiveness of budget allocations are highly understudied in the context of agricultural institutions, it's evident that resources, such as funding, can be limited and limiting, especially at nonprofits and commodity organizations (Kohn & Anderson, 2022; Suh, 2022). Importantly, all but one of the six participants in Strategize on a Budget were associated with a non-profit or commodity organization.

Moreover, lack of revenue streams and funding sources often result in a lower adoption rate and use of ICT (Ihm & Kim, 2021), which are part of an essential pillar to the KE framework, as ICT infrastructure is how knowledge is shared (Powell & Snellman, 2004; Unger, 2022). However, even if there are sufficient revenue streams and funding sources sustaining a budget for an organization, the amount of money allocated to communication efforts varies in capacity. Thus, employers commonly seek professionals who can maximize communication output and quality while minimizing the use of resources necessary for developing and executing communication activities (Entradas et al., 2020).

One cost-effective means of disseminating information is through digital media (Yadav et al., 2015) and participants in Strategize on a Budget, Empathize with Audiences and Leverage Communication Technology, and Exude Credibility and Communicate Quickly gave a relatively high ranking to using digital media to communicate information. Most digital media are highly accessible to a variety of audiences (Bala & Verma, 2018), and they often provide opportunities for two-way communications, such as experts responding to questions regarding scientific topics in agriculture with users on Twitter/X (Insall, 2023). Additionally, certain forms of digital media such as social media allow for quick, almost real-time communications (Bala & Verma, 2018; Yadav et al., 2015), something that's especially important to participants in Exude Credibility and Communicate Quickly. Lastly, there are ample ways to innovatively and creatively communicate science using digital media, whether through podcasts (Fox et al., 2021), social media memes (Riser et al., 2020), or YouTube videos (Kaul et al., 2020). However, as mentioned previously, not everyone has equitable access to every form of digital media, as not everyone has access to the same ICT infrastructure (Tiwari, 2022). Also, not every person values digital media over traditional forms of media, like print, television, and radio (Fox et al., 2021). Thus, solely relying on digital media as a means of communicating with the public could result in the exclusion and/or underrepresentation of certain groups of people (Canfield et al., 2020) . This is also why identifying and considering stakeholders' diverse communication needs, wants, and preferences is considered important by many science communication trainers (McBeth et al., 2016), and this skill was ranked relatively high in importance by all factors accept Exude Confidence and Engage Audiences.

Implications and Recommendations for Science Communication Curricula

While there are varying viewpoints regarding the importance of science communication skills within the agriculture industry, all skills used in this study are arguably important in one way or another. Most participants mentioned how they had difficulty ranking any of the skills as 'less important' than others. However, this study identified which skills are prioritized by leaders with differing roles and from differing sectors within the agriculture industry, thus illuminating specific skillsets that may need to be more intensely focused on in science communication training programs, such as university-level curricula. This is not to say that other skills that weren't necessarily prioritized should be ignored in curriculum development, but rather they should be emphasized to a lesser extent. Alternatively, science communication curricula could involve the development of skills that industry leaders most prioritize along with the skills that scholars most prioritize in a more balanced manner, as the most effective curricula are balanced in practice and theory (Mercer-Mapstone & Kuchel, 2017). Thus, it's recommended that the findings from this study be used to guide collaboration efforts between the agriculture industry and the university to inform science communication curricula.

It's also important to consider how 'effective' science communication is scenario-dependent, meaning that different goals and even different organizations might regard different outcomes as successful, thus requiring different science communication skills from professionals (Intemann, 2022, 2023). For example, if the goal of an organization is to empower decision makers to make logical and evidence-based decisions with respect to science, it might make more sense for professionals within that organization to have stronger debate and persuasion skills (Priest, 2013). Similarly, different roles require different skills. A public relations manager, for instance, might need to have more skills regarding engaging audiences in two-way communication as opposed to, for example, skills regarding conducting research and analyzing data (Flynn, 2014). Nonetheless, communication skills in general, whether regarding science or not, are highly valued among all professions and professionals (Kumar & Lata, 2011). Having strong interpersonal communication skills, or 'people' skills, which is closely related to working well with teams, allows for collaboration, growth, and positive outcomes for companies within every industry (Warrner, 2021).

Overall, based on the insights from industry leaders within Georgia's agriculture industry we recommend that science communication curricula at the university level emphasize skills related to strategically and intentionally planning communication initiatives, appearing trustworthy and credible at all times, ensuring that any information shared is accurate and relevant and appears that way to intended audiences, disseminating information in a timely manner, making sure messages are digestible and understandable, and working with budget constraints. These skills are especially important for professionals within the agriculture industry who work for nonprofits and commodity boards. Curricula should also involve the development of skills related to engaging citizens democratically regarding scientific issues and topics, participating with the public in policy making, engaging audiences through two-way communication, and exuding confidence during communication activities. These skills are especially important for professionals who work for organizations that focus on influencing agriculture-related legislation. Skills that are more technical, such as conducting communication-related research, communicating through writing, communicating orally, and setting up a display/exhibit, should be less focused on than skills that involve strategizing, engaging, and intentionally developing messages.

Limitations and Recommendations for Future Research

Regarding the implications of this study for future research, using the KE framework along with the UIC model as a conceptual framework was useful in terms of developing a big-picture perspective on how knowledge flows among actors on a multidimensional level. For instance, scientific knowledge can flow from researchers to agriculturalists to consumers, just as knowledge regarding what the most important science communication skills are can flow from industry leaders to academia leaders to future professionals. The flow of knowledge requires effective communication and thus ICT infrastructure and overall results in increased innovation and economic expansion (Unger, 2022). The novel contribution this study makes to existing literature is that it’s the first to apply the KE and UIC conceptual framework to a Q methodological study, and it’s the first to identify nuanced science communication skill prioritizations for future professionals to have within Georgia’s agriculture industry. Thus, the insights from this study are intended to guide decision-making processes during science communication curricula development.

As evidence-based and balanced curricula also require theoretical underpinnings, one recommendation for research moving forward includes examining the viewpoints of leaders within academia, specifically within UGA's CAES since it's a land-grant university in the state of Georgia (*Public Service and Outreach* 2023), and curricula within it heavily pertains to Georgia's agriculture industry. Moreover, this would allow for industry leaders to engage in conversation with university leaders, thus completing the 'missing piece' to the UIC model. Also, this study only focused on perspectives in relation to Georgia's agriculture industry, thus findings aren't generalizable to agriculture industries in other states—however, applying the conceptual framework as well as the Q set used in this study to similar research efforts in other states could be beneficial. Also, a very select group of individuals were selected as participants, as they were all past, current, or board members of AGL. Therefore, conclusions from this study are only generalizable to these groups, and future research could focus attention on the perspectives of other groups. Furthermore, leaders in industry are not the only actors involved in the process of science communication within the agriculture industry—further research is needed regarding other (particularly underrepresented) stakeholder's perceptions of the importance of various science communication skills, or at least what effective science communication means to them (Canfield et al., 2020).

Regarding the application of Q methodology in this study, it did help gain nuanced perspectives among target participant groups, but there are other methods and methodologies (e.g., focus groups, interviews, surveys, Delphi methods, etc.) that could've been used to achieve the same research objectives but with differing results and avenues for interpretation. Therefore, future research could involve conducting a study with the same objectives as the present study but using a different methodology. Additionally, there's potential that not all possible or relevant skills were mentioned in the Q set, and it's possible that the wording of skills could have influenced participants' sorting processes. Thus, future research could involve further optimization of the Q set.

Lastly, the agriculture industry and the communication landscape are constantly evolving (Alam et al., 2023; Hadlington et al., 2023; Moser, 2020), and while the present study is future-oriented since some skills were 'harvested' from articles discussing the future of the agriculture industry, it only applies to a specific timeframe. Continuous research and university-industry collaboration is needed to ensure the development and implementation of consistently up-to-date and relevant science communication practices and training.

Conclusion

The purpose of this study was to identify nuanced perspectives regarding the importance of various science communication skills from leaders in Georgia's agriculture industry to help inform science communication curricula at the university level and contribute to more effective science communication practices within the industry. This study was one of the first to apply the KE framework and the UIC model to a Q study investigating the perspectives of leaders in Georgia's agriculture industry, and future studies should build from this by using the novel conceptual framework or other frameworks such as human capital theory (Becker, 2009) and knowledge flows, spillovers, and externalities (Karlsson & Gråsjö, 2021) to further explore agriculture industry leaders' nuanced perspectives regarding skill importance through Q methodology.

Q methodology allowed for the discovery of four primary viewpoints, or prioritized skillsets, among participants, which were Strategize on a Budget, Empathize with Audiences and Leverage Communication Technology, Exude Credibility and Communicate Quickly, and Exude

Confidence and Engage Audiences. These viewpoints are distinct in certain ways but also contain a lot of overlap among them, thus indicating that there are specific skills that should be emphasized more so for specific programs while other skills should be emphasized across all science-based programs. Thus, the development of teaching resources that strategically guide science communication trainers through applying industry input to training programs and curricula could be beneficial.

While there has been an overall struggle to define effective science communication and identify key skills that result in effective science communication within the agriculture industry, the use of Q methodology is a promising opportunity to continue defining and exploring science communication in the agriculture industry in a nuanced, detailed manner (Watts & Stenner, 2012). Moreover, participants who engaged in this study reported enjoying the study activities and that the Q-sort exercise forced them to think critically and analytically about what effective science communication both looks like and requires within their respective fields, thus resulting in the collection of rich and meaningful data. Hopefully this work will inspire future research to focus on industry perspectives in a novel way, through combining and applying both qualitative and quantitative measures to explore science communication skillsets.

CHAPTER FOUR: INFORMING SCIENCE COMMUNICATION CURRICULUM DEVELOPMENT: ACADEMIA LEADERS' PERCEPTIONS OF IMPORTANT SCIENCE COMMUNICATION SKILLS WITHIN THE AGRICULTURE INDUSTRY[2]

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Abstract

Science communication encompasses a diverse array of disciplines and definitions and is constantly evolving along with advancements in science and technology. This is particularly true in the context of agriculture, which involves many scientific and technological innovations. As these innovations become more and more complex within the agriculture industry, more effective science communication from the agriculture workforce will be required to maintain stakeholder support and buy-in for agriculture, especially considering the numerous channels and media platforms through which various communication challenges have surfaced. One way to move forward in enhancing effective science communication within the agriculture industry is by improving science communication training and curricula at the university level through fostering UIC, as many scientists and other professionals who work within the agriculture industry have a degree from a university. Thus, Q methodology was used to explore nuanced perspectives among academia leaders in Georgia regarding the importance of science communication skills within the context of the agriculture industry. Four prevailing factors emerged, each representing a prioritized skillset: Think Logically and Adapt Quickly (F1), Communicate Intentionally and Defend Science (F2), Think Ahead and Communicate in Diverse Ways (F3), and Communicate Efficiently and Engage Audiences (F4). Each factor is described and compared. Implications and recommendations for the development of university-level science communication curricula are considered, and future research opportunities that could further establish Q methodology as a useful means of understanding perspectives regarding science communication curricula at the university level and within the context of agriculture are discussed.

Introduction

Science communication encompasses a diverse array of disciplines and definitions (Mercer-Mapstone & Kuchel, 2017; Mulder et al., 2008), and it is constantly evolving along with advancements in science and technology (Reincke et al., 2020; Schäfer, 2023). This is particularly true in the context of sustainable agriculture, which involves many scientific and technological innovations (Bhat & Huang, 2021; Bonnen, 2019; Stofer & Newberry, 2017; Weiner, 2003). As these innovations become more and more complex within the agriculture industry, more effective science communication from the agriculture workforce will be required to maintain stakeholder support and buy-in for sustainable agriculture (Intemann, 2023; Monteiro et al., 2021; Ruth et al., 2018). Moreover, research showed that interdisciplinary agricultural research center directors from top research, land-grant institutions believe teaching and engaging in science communication is essential to serving the public (McLeod-Morin et al., 2020); and communication programs might benefit from more heavily incorporating science communication research agendas (Parrella et al., 2023).

Many scientists and other professionals who work within the agriculture industry have a degree from a university (Jelks & Crain, 2020; Rodrigues et al., 2007), yet, they often lack formal communications training during their degree programs (Simis et al., 2016; Washburn et al., 2022). Therefore, scientists or other future professionals pursuing majors related to any science-based discipline (e.g., chemistry, agroecology, food sciences, etc.) commonly aren't subjected to courses that explicitly and intentionally focus on communication skills. This is especially true for the hard sciences, or sciences in which the beliefs, attitudes, and perspectives of humans are rarely formally incorporated into the research lens (Rowland & Kuchel, 2023).

Another factor that influences science communication curricula is how universities often base their curricula on scholarly theories rather than work-based experience (Doerfert & Miller, 2006; Ellahi et al., 2019; Kemp et al., 2021; Mercer-Mapstone & Kuchel, 2017). This is problematic because professionals need more work-based experience and knowledge to more intentionally and effectively serve the institutions at which they are employed (Mercer-Mapstone & Kuchel, 2017; Sarkar et al., 2020). Many contend that the current university system often better prepares students to become graduate students who conduct research rather than professionals within an industry (Kemp et al., 2021; Mercer-Mapstone & Kuchel, 2017; Sarkar et al., 2020).

However, there is research that indicates the potential of more effective science communication curricula at the university level (McLeod-Morin et al., 2020; Mercer-Mapstone & Kuchel, 2017; Parrella et al., 2023; Washburn et al., 2022). One example involves how researchers developed recommendations for enhancing science communication course content at the university level by exploring demands and constraints on scientists trying to communicate science (Washburn et al., 2022). Additionally, researchers posited how science communication is taught most effectively when the skills involved are tailored to specific educational contexts and developed a teaching resource for undergraduate science communication curriculum that is evidence-based and reflective of theory and practice, creating a more balanced focus between theory and practicality within university-level curriculum (Washburn et al., 2022).

To help foster the necessary balance, university-industry collaboration (UIC) can help aid in this process by universities consulting with industries of interest and engage in discussions regarding what both sides want to incorporate into curriculum (Erkarslan & Aykul, 2018; Ishengoma & Vaaland, 2016; Nangia & Pramanik, 2011; Spier, 1995). Furthermore, through

UIC, universities can better prepare students to not only become more effective science communicators but also increase students' employability (Kemp et al., 2021; Rowland & Kuchel, 2023). Preparing students for professional success is one of the primary goals of academic institutions, particularly land-grant institutions (Law et al., 2021)

Therefore, the present study contributes solutions to the need for more effective science communication curricula at the university level by identifying which skills related to science communication are perceived as most necessary for future professionals to have according to leaders in academia. This information could help strengthen the UIC and encourage more intentional collaboration regarding science communication curricula development at the university level, ultimately resulting in more prepared agriculture professionals as science communicators at the professional level, more effective science communication within the agricultural industry, and a greater number of citizens who trust and support the agricultural industry. Findings from this study could be applied to broader contexts, such as science communication curricula development at other land-grant universities.

Literature Review and Conceptual Framework

The Knowledge Economy (KE) Framework Applied to the State Level

There is a need for innovation in agriculture, as this is what drives efficiency and sustainability (Herrero et al., 2021; Moser, 2020; Qayyum et al., 2023; Rose et al., 2021). Moreover, efficiency and sustainability is necessary considering the current and impending challenges of feeding a growing population, which is projected to reach 10 billion by 2050 and require a 60%–100% increase in food production worldwide (Alfred et al., 2021; Bhat & Huang, 2021; McFadden et al., 2023; Monteiro et al., 2021). However, for sustainable and innovative agricultural practices and technologies to persist, they must be supported by a variety of audiences, such as farmers, consumers, policymakers, and other stakeholders (Eidt et al., 2020; Lindberg et al., 2023).

Communicating information effectively is key to building and maintaining stakeholder support (Alamanos et al., 2021; Bourne, 2016), and this is an important point considering the United States (along with other developed countries) is involved in a KE. The KE, which is considered to be the main engine of economic growth in developed countries (Berkes & Gaetani, 2023; Powell & Snellman, 2004), was developed conceptually in the 1960s by various economic and social scholars (Powell & Snellman, 2004) and refers to an economy in which economic activities rely on non–routine, non-manual technical skills, intellectual creativity, and scientific knowledge (Berkes & Gaetani, 2023; Powell & Snellman, 2004). It has also been described as "the accumulation of capital, technology, technology-relevant capabilities, and science in the conduct of productive activity" (Unger, 2022, p. 20) and is considered to be the main engine of economic growth in developed countries (Berkes & Gaetani, 2023; Powell & Snellman, 2004). Importantly, communication plays an essential role in KEs because it is the primary way in which information is shared and received via communication infrastructure and technology (ICT) (Hadad, 2017; Tiwari, 2022), thus allowing for more individuals and entities to enter the KE and contribute to, as well as benefit from, its growth and expansion (Unger, 2022).

The KE consists of four primary pillars within a global or national economy, which are economic and institutional regime, well-educated and skilled population, ICT infrastructure, and innovation system (Chen & Dahlman, 2005). The KE involves every economic sector from the global, national, regional, and state perspective and is very relevant in terms of the agriculture industry (Tiwari, 2022; Unger, 2022). In the current study, the KE was used as a framework for conceptualizing the flow of information and productivity related to agriculture within the context of a state-level economy. As Georgia's agriculture industry contributes approximately $69.4 billion to the state's economy annually ((*About Georgia Ag*, 2023), Georgia is the state of interest. Also, Georgia is home to a land-grant university known as the University of Georgia (UGA), which also has an $8.1 billion impact on Georgia's economy annually and has a land-grant mission to teach, serve, engage in research, and foster scientific and agricultural innovation (*Office of the President* 2023). Therefore, Table 3.1 defines the four context-independent pillars of the KE while also establishing a state-specific context for the purposes of framing the study.

Table 4.1.
The Knowledge Economy (KE) Framework Applied to the State Levels

Pillar	**General description (broad context)**	**State-level description (specific context)**
Economic and institutional regime	Any regime that provides incentives encouraging the use and spread of existing and new knowledge in an efficient manner, thus supporting creation and innovation. The economic environment is favorable to market transactions and the government encourages entrepreneurship and invests in knowledge sharing.	The state government and economy of Georgia, both of which provide incentives to foster and support knowledge sharing and economic growth (MacLeod & Urquiola, 2021).
Well-educated and skilled population	A population that forms, disseminates, and applies knowledge in an efficient manner. Education plays a crucial role here, as it is necessary for the acquiring and application of knowledge and technological/scientific advancement.	Georgia citizens and Georgia's agriculture industry, as these comprise the individuals and entities who create, share, and apply knowledge to apply and innovate. Future professionals in the agriculture industry also exist here.
Information and communication technologies (ICT) infrastructure	Infrastructure that facilitates the communication, dissemination, and processing of information and technology. As efficiency of facilitation increases, there is greater	Infrastructure within Georgia that facilitates the communication, dissemination, and processing of information and technology—e.g., social

	communication, productivity, and output.	media, television, Extension, websites, etc.
Innovation system	Systems that involve firms, universities, research centers, think tanks, etc. that use and apply knowledge to create new technology, leading to productivity growth.	The University of Georgia as a research center, as it is an institution with a land-grant mission to apply knowledge and contribute to productivity growth. Students at the university are also found here, as they are learners and researchers that have the potential to contribute to productivity growth as future professionals.

Each pillar plays a different role in the development of the state-level KE, which can be seen in Figure 4.1. Pillar 1 involves the state government and economy, which incentivizes research, innovation, and productivity through funding and investments in various institutions and infrastructures, a viable market economy, and related policies (MacLeod & Urquiola, 2021). Pillar 2 involves professionals within the state's agriculture industry as well as the state's citizens, including policymakers, consumers, and farmers. Pillar 3 involves the infrastructure available for disseminating and receiving information, which is used to facilitate knowledge among actors within each of the other three pillars. Finally, Pillar 4 involves the university as an innovative system and educational institution in which future professionals are trained to enter the workforce of the agriculture industry.

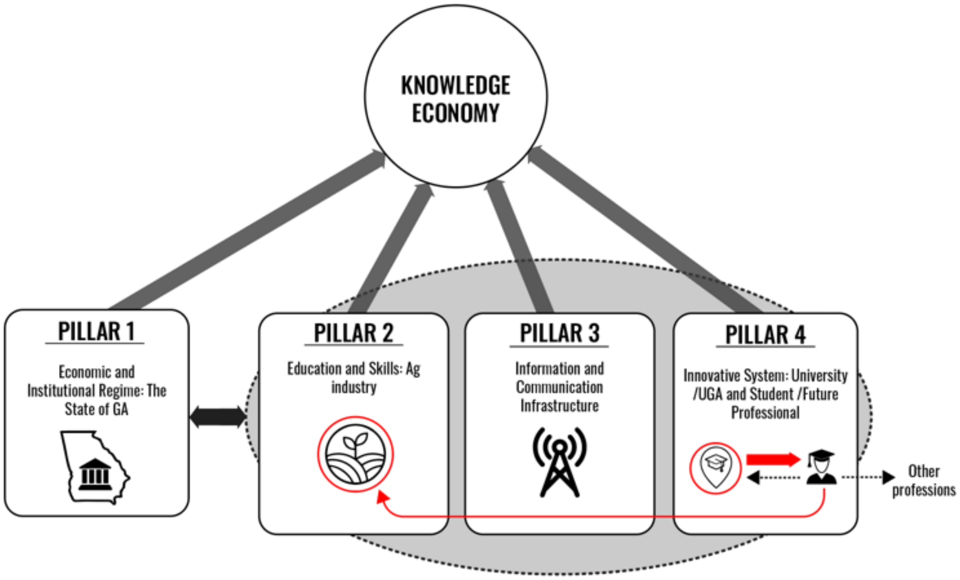

Figure 4.1
The KE Framework Applied to the State Level

A double-sided arrow exists between the student/future professional and the university, as a portion of students do enroll in graduate school and contribute their knowledge and skills back to the university through engaging in research (Li, 2022). Also, not all students join the agriculture industry as professionals, even if they were enrolled in degree programs that intend to prepare them for that specific workforce. This is why an arrow exists extending from the student to 'Other professions'.

The University-Industry Collaboration (UIC) Model

Regarding the ICT Infrastructure pillar of KE, one way in which actors within the KE communicate information is through conversation and collaboration (Hadad, 2017; Li, 2022; Tiwari, 2022; Unger, 2022). For the present study, professionals within the agriculture industry and professionals within academia can potentially share their knowledge regarding important science communication skills, as the former can give insight into practical, work-based skills and the latter can give insight into theory-based skills, both of which could inform more effective science communication curricula at the university level. This process, known as university-industry collaboration (UIC), allows for universities to consult with industries of interest and engage in discussions regarding what both sides want to incorporate into curriculum (Erkarslan & Aykul, 2018; Ishengoma & Vaaland, 2016; Nangia & Pramanik, 2011; Spier, 1995).

Curricula that are exemplary results of this process include a co-operative model based on a Plan–Do–Study–Act cycle that was applied in the curriculum design of two courses in welding within a manufacturing engineering master's program (Valiente Bermejo et al., 2022), a teaching resource for undergraduate science communication curriculum development (Mercer-Mapstone & Kuchel, 2017), and a co-designed and co-delivered curriculum focused on enhancing students' data literacy skills for students to succeed in the labor market within the digital era (Taş, 2023).

The addition of UIC to the KE framework at the state level can be seen in Figure 4.2. As the goal of UIC is to co-create knowledge through collaboration, leaders in academia at the university engage with leaders within the agriculture industry in equal proportion, thus why collaboration is in the center of the communication scale. Moreover, silence (zero collaboration) occurs when there is no infrastructure in place for conversation to occur, and conflict (also zero collaboration) occurs when either entity is unwilling to contribute to the conversation in a meaningful or productive manner (Rajalo & Vadi, 2017; Rose-Anderssen & Allen, 2008; Wright, 2017). Overall, effective UIC within the context of the KE could allow for the acquirement and co-creation of meaningful knowledge that could help foster the development process of science communication curricula that's evidence-based and balanced in theory and practice.

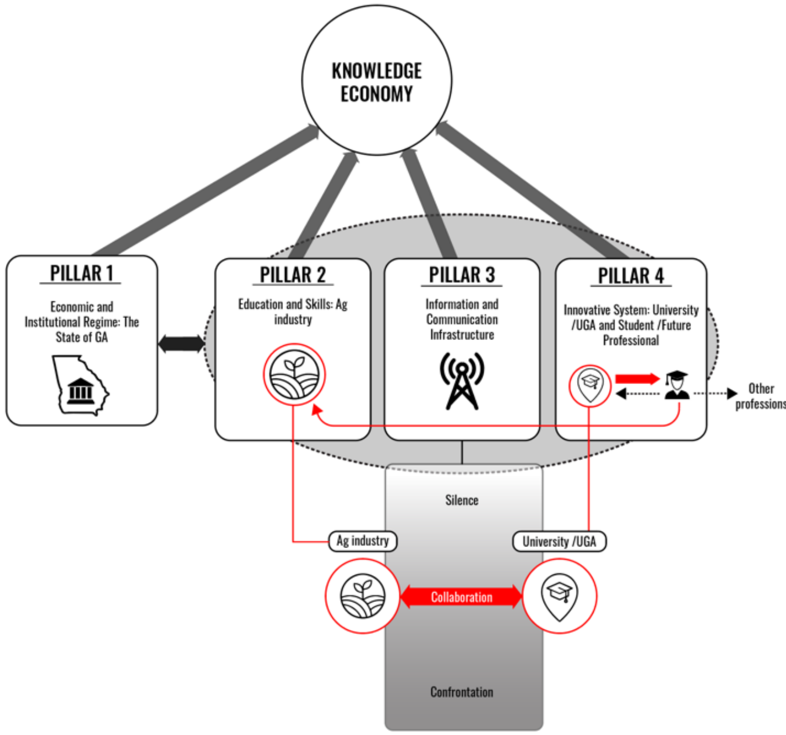

Figure 4.2
The KE Framework Applied to the State Level and UIC

Purpose and Objectives

The purpose of this study was to explore shared and unshared viewpoints among leaders in in academia at the University of Georgia (UGA) regarding the importance of various science communication skills within Georgia's agricultural industry, as well as to understand how to most effectively gain meaningful insight regarding the shared viewpoints of leaders in academia to begin forming a base for more effective science communication curriculum at the university level. Using a conceptual framework consisting of the pillars of the Knowledge Economy (KE) and the addition of the university-industry collaboration (UIC) model, the following research objectives guided this study for chapter 4:

1. Describe the sociodemographic characteristics of leaders in academia within UGA's College of Agricultural and Environmental Sciences.
2. Explore academia leaders' perceptions of levels of importance of various skills related to communicating science within Georgia's agricultural industry.
3. Examine shared and nuanced viewpoints among leaders in academia regarding levels of importance of various skills related to communicating science within Georgia's agricultural industry.

Methods

General Overview of Q Methodology

Q methodology, which was developed by William Stephenson in the 1930s, is a methodology that allows for accessing subjective viewpoints through both qualitative and quantitative methods and is especially useful when exploring personal experiences, values, and beliefs. While it has been used most commonly in the sociology, education, and political sciences (Gao & Soranzo, 2020; Hedges, 2014; Lehtonen & Aalto, 2016), it has also been used in studies with foci similar to the focus of this study, such as identifying and exploring resilience skill types among nurses (Shin et al., 2018), professional development format preferences (DeVore-Wedding et al., 2018), teachers' viewpoints about global food insecurity (Spence, 2023), industry leader perspectives (Nicholson & Cushman, 2000), and training preferences (Irie et al., 2018).

There are few studies in the literature examining academia leaders' perceptions of science communication, and they most commonly involve methodologies that incorporate Likert scales, interviews, focus groups, etc. to measure subjective data (Sinclair & Phillips, 2019; Smalley et al., 2016). To the best of our knowledge, no studies have incorporated Q methodology to understand the nuances in academia leaders' perceptions of science communication skills. Therefore, Q methodology is a novel and potentially promising methodology for this study.

Furthermore, Q methodology is useful when a certain group of people's viewpoints are considerably important relative to a specific subject matter (Watts & Stenner, 2012). In this study, UGA's academia leaders are the people who have the most knowledge about various curricula within the CAES, and they are accepted experts within their field. Thus, their perceptions of science communication are essential in terms of understanding which skills would increase students' employability as well as their effectiveness as science communicators within the agricultural industry. For example, academia leaders might think differently from industry about how the public best receives information, and discovering these differences in perspectives could potentially lead to productive conversation between academia and industry (Erkarslan & Aykul, 2018; Ishengoma & Vaaland, 2016; Nangia & Pramanik, 2011; Spier, 1995).

The method through which Q methodology is practiced is known as the Q-sort. This involves selected participants ranking several items prepared by the researcher (i.e., statements, images, etc.) on a given scale involving some subjective dimension (i.e., least agree to most agree, or least prefer to most prefer), allowing for participants to portray their personal viewpoints on a particular issue or topic. Then, after the Q-sorts have been intercorrelated, the researcher conducts a by-person factor analysis of the sorts. This analysis process involves comparing the different sorting patterns among participants through detecting any '...shared modes of engagement, orientations, or forms of understanding…' (Stenner et al., 2000, p. 442). A visualization of all steps involved in conducting a study using Q methodology can be seen In Figure 4.3.

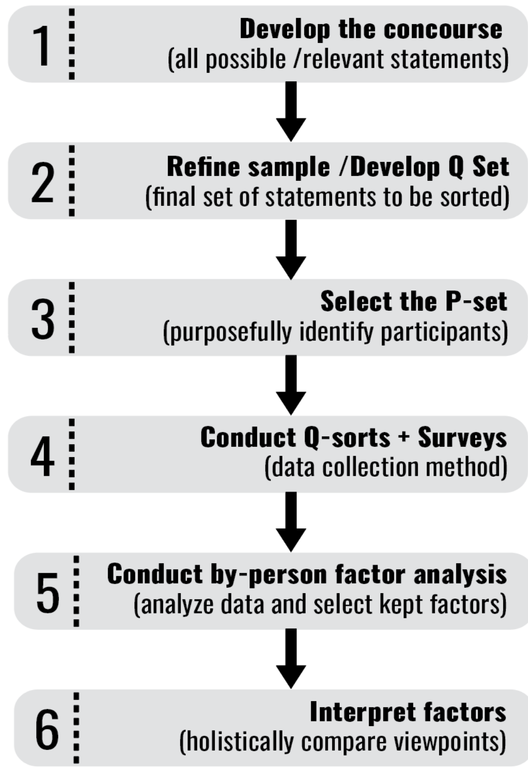

Figure 4.3
Steps for Conducting a Q Methodology Study

Concourse and Q Set

As the researcher prepares the items into a Q set ranked by the participants, this collection of items is derived from a larger concourse, which can either be theoretically structured or unstructured. Structured refers to the selection of concourse items based on previously identified theoretical assumptions or concepts, which are each represented by a certain number of items, and unstructured means the aim isn't necessarily to represent assumptions or concepts but to reveal varying positions on a specific variable (Lobinger & Brantner, 2019).

For the present study, the concourse was developed in an unstructured manner by 'harvesting' statements from seven peer-reviewed articles that the researcher and the research committee agreed mentioned most, if not all, possible skills that would be associated with science communication within the context of agriculture (Bongomin et al., 2020; Doerfert & Miller, 2006; Kurtzo et al., 2016; Mercer-Mapstone & Kuchel, 2017; Metcalfe, 2019; Oliveira et al., 2021; Shivni et al., 2021). Moreover, they involved multiple aspects of communication and included skills that might be necessary in future industry landscapes, as implications of Industry 4.0 and Agriculture 4.0 were considered (these are phases of industries in which information and knowledge exchange, as well as scientific and technological innovations, are what drive economic development (Alam et al., 2023; Liu et al., 2020; Rose et al., 2021). Over 100 initial statements were harvested. Then, any repeat statements, double-barreled statements, or irrelevant statements were deleted. Irrelevant statements included any statements that were considered a competency (a knowledge area or understanding of something, such as 'understanding how policies are made'), any technology related skills not quite related to communication (such as Big Data, IoT, IT skills, etc.), and any personal skills that were too broad or not directly relevant enough to the study (such as hard worker, good with managing time, etc.).

After three rounds of careful consideration among a team of professors within the Agricultural Leadership, Education, and Communication department at UGA, a total of 39 statements were selected for the final Q set. Grammar of each statement was changed to help with sentence structure consistency. A chart of the articles and the statements harvested from them can be seen in Table 4.2.

Table 4.2
Articles From Which Q-Set Statements Were Harvested

Article References	Harvested Skill
1. Mercer-Mapstone, L. & Kuchel, L. (2017). Core Skills for Effective Science Communication: A Teaching Resource for Undergraduate Science Education. *International Journal of Science Education, Part B, 7*(2), 181-201.	S08, S09, S22, S23, S03, S07, S30
2. Doerfert, L. D. & Miller, P. R. (2006). What Are Agriculture Industry Professionals Trying to Tell Us? Implications for University-Level Agricultural Communications Curricula. *Journal of Applied Communications, 90*(3).	S13, S20, S36, S11, S17, S27, S28, S32, S18
3. Bongomin, O., Ocen, G. G., Nganyi, E. O., Musinguzi, A., Omara, T. (2020). Exponential Disruptive Technologies and the Required Skills of Industry 4.0. *Journal of Engineering*, (*2020).*	S01, S37, S02, S35, S07, S10, S12, S31
4. Kurtzo, F., Jo Hansen, M., Rucker, K. J., and Edgar, L. D. (2016). Agricultural Communications: Perspectives from the Experts. *Journal of Applied Communications, (100)*1.	S19, S21, S26, S05, S03, S07, S30, S38, S29, S31, S34
5. Metcalfe, J. (2019). Comparing science communication theory with practice: An assessment and critique using Australian data. *Public Understanding of Science*, *28*(4), 382–400.	S04, S05, S14, S39, S06, S15, S24, S33
6. Shivni, R., Cline, C., Newport, M., Yuan, S., and Bergan-Roller, H. E. (2021). Establishing a baseline of science communication skills in an undergraduate environmental science course. *International Journal of STEM Education, 8*(47).	S25, S03, S07, S31
7. Oliveira, Alandeom & Brown, Adam & Carroll, Marissa & Blenkarn, Elizabeth & Austin, Bradley & Bretzlaff, Tiffany. (2021). Developing undergraduate student oral science communication through video reflection. *International Journal of Science Education, Part B. 11,* 1-12.	S16, S03, S07, S30, S24, S31

Note. Some statements were harvested from multiple articles and are thus listed more than once. Statements can be seen in Table 4.5.

P Set and Procedures

The sample size for Q methodology is recommended to be much smaller than common sample sizes for quantitative studies, as this allows for a more intentional capturing of various viewpoints to enhance quality. Furthermore, the P set is determined once a salience of potentially unique viewpoints is reached (Brown, 1980; McKeown & Thomas, 2013; Watts & Stenner, 2012). Importantly, this approach is intended to reveal the different perspectives within a specific group rather than result in generalizable conclusions (Brown, 1980). For this study, the target participant group was department chairs, deans, and alumni relations coordinators of UGA's CAES, as they make many decisions regarding curriculum development and implementation and are familiar with industry professional landscapes related to agriculture (Bisbee, 2007; Schauer, 2002). Moreover, the departments within CAES—which include Agricultural and Applied Economics; Agricultural Leadership, Education, and Communication; Animal and Dairy Science; Crop and Soil Sciences; Entomology; Food Science and Technology; Horticulture; Plant Pathology; Poultry Science; and Plant Breeding and Genomics (College of Agricultural and Environmental Sciences, 2023)—cover a wide range of agricultural sectors, and representation from each department is crucial to include different perspectives, based on the disciplines represented, on the importance of various science communication skills.

Upon agreeing to participate, 13 potential participants were contacted by the lead researcher via email with instructions on how to participate in the study, which was distributed through a web-based software program known as QMethod Software (qmethodsoftware.com). A total of 13 leaders in CAES completed the study activities between January 2024 and March 2024. Institutional Review Board (IRB) approval for the study was received in October 2023.

To complete the web-based survey, participants were asked to read through all 39 skill statements and place them into three piles according to their initial agreement, neutrality, and disagreement. The participants were then asked to rank the statements on the Q sorting grid from most unimportant (-5) to most important (+5), with neutral (0) in the center of the forced-choice frequency distribution (ex: 'S21: +3). A prompt stating "When considering the skills needed to effectively communicate science within the area/field of Georgia's agriculture industry with which you're engaged as a leader, it's important that employees have the ability to [blank]" guided the participants' sorting decisions. Additionally, participants were asked to consider their sorting decisions in terms of which science communication skills they believe future professionals need to be taught while enrolled in a degree program. Following the conclusion of the Q sorting, participants were asked to complete a post-sort survey in which they explained their rationale for their sorting processes and provide any additional thoughts or opinions they had about the exercise. Demographic data was also collected via the post-sort survey. Figure 4.4 displays the sorting grid that was used by participants during the Q sorting exercises on qmethodsoftware.com.

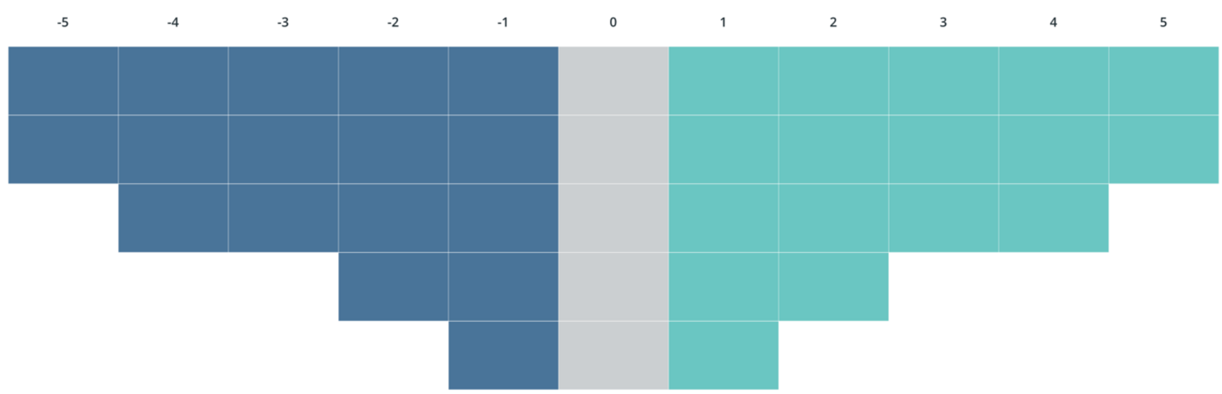

Figure 4.4
Q-sort Distribution Grid

Note. Blocks in the -5 column represent 'most unimportant' skills, and blocks in the +5 column represent 'most important' skills. Rankings vertically have no value. Only rankings horizontally matter during the data analysis process.

Statistical Analysis

QMethod Software allows for both the collection and analysis of data, thus data was analyzed in this software following data collection. An intercorrelation matrix of the participants' Q sorts was constructed to calculate the positive or negative relationships between each individual Q sort. By subjecting the matrix to principal components analysis (PCA) and factor-analysis on a by-person basis, correlations were identified next, allowing for the identification of statistically significant factors in which very similar perspectives across Q sorts are grouped into corresponding factors. Eight unrotated factors were initially yielded that accounted for 88.52% of the total variance. These eight unrotated factors are merged Q sorts that represent shared viewpoints and form a single Q sort that best represents each of the merged Q sorts through a weighted average. However, it is recommended to only keep factors with an eigenvalue of 1 or more (Brown, 1980). Thus, four factors met this criterion.

Critical to the direction of the study is deciding the number of kept factors for final analysis (McKeown & Thomas, 2013), but there is no objective process for deciding the most appropriate number of factors to keep (Aragao Pereira, 2011). Nonetheless, potential concerns of the suitability of kept factors were considered, such as applying the significance criterion, which means each factor kept for rotation must have two or more significant Q sort loadings (Watts & Stenner, 2012). A real-world reflection of the factors kept for analysis was also considered (Watts & Stenner, 2012), and this involves considering the weight of importance of various participants' perspectives. Four meaningful factors were kept for varimax rotation after further consideration of the factors. 13 of the 13 Q sorts loaded significantly onto one of these four factors, explaining 66.34% of the total study variance. As the minimum threshold for a loading value is at 0.41 ($2.58 \times 1/\sqrt{}$ (number of statements) $= 2.58 \times 1/\sqrt{39}$) (Stenner & Watts, 2012), all participants loaded significantly onto a single factor because their viewpoints were distinct from the viewpoints of other factors. Factor correlations can be seen in Table 4.3.

Table 4.3
Correlations Between Each Identified Factor

	Factor 1	Factor 2	Factor 3	Factor 4
Factor 1	1.00	0.3114	0.4080	0.4632
Factor 2	0.3114	1.00	0.4458	0.1789
Factor 3	0.4080	0.4458	1.00	0.2686
Factor 4	0.4632	0.1789	0.2686	1.00

Note. A relatively low correlation between each of the factors exceeds the study's significance level of 0.41, which reveals that viewpoints among factors are distinct. Each factor represents the common viewpoints among a group of Q sorts that were ranked in very similar manners.

Finally, to develop a qualitative picture of the individual perspectives within each of the extracted factors, the crib sheet method was applied to the data in this study (Watts & Stenner, 2012), which systematically and holistically examines the results of this study through revealing patterns and unique viewpoints within each of the identified factors (Watts & Stenner, 2012). Using this method, the researcher must consider every item within the factor array rather than just considering higher or lower ranked items, as well as consider other potentially influential data like demographic data of the participants and post-sort reflections (Watts & Stenner, 2012). The crib sheet method involves organizing statements based on their relative rankings in comparison to the other factors, which is accomplished by placing the statements in four groups: the highest ranked statements in each factor, the lowest ranked statements in each factor, statements ranked higher in one factor compared to any other factors, and statements ranked lower in one factor compared to any other factor. This process allows for an interpretation that is both organized and all-encompassing, as the implications of every statement placement are considered, any polarized statements are acknowledged, and all statements that profoundly contribute to each individual factor are identified (Watts & Stenner, 2012). In essence, it is a big-picture and simultaneously detail-oriented manner of exploring data extracted via the Q method.

Results

Purposive sampling measures were used to ensure potentially diverse perspectives regarding the research question. The characteristics of the participants represented in this sample somewhat achieved the goal of diversification. Academia leaders in this study were 25 to 65+ years of age, and more than half were male (61.54%) while slightly under half were female (38.46%). Racially speaking, all but one of the participants identified as Caucasian (92.31%). Participants indicated living in Georgia for a variety of time lengths, but the majority have lived in Georgia for at least 6 years (69.23%). Similarly, participants indicated holding their leadership positions in academia for a variety of time lengths, but over half have held their leadership position for at least 6 years (53.85%). Department chairs from every department within the CAES were represented in this sample (69.23%), and two deans (15.38%) and two alumni relations coordinators (15.38%) were also represented. The leaders' primary foci regarding their departments and the agriculture industry included one or more of the following: research, services and support, management, production, education, and leadership. While there were some differences between the characteristics of leaders and their associated departments/foci within each study factor, no statistical tests were used for this data set. Demographic data is presented in Table 4.4 and is solely meant to provide relevant descriptive information for this study.

Table 4.4
Demographic Characteristics of Study Participants in Each Identified Factor

	F1	F2	F3	F4	Total
Number of academia leaders	5	3	3	2	13
Age range (based on brackets)					
Range	25-65+	35-64	45-54	35-64	25-65+
25-34	1	0	0	0	1 (7.69%)
35-44	0	1	0	1	2 (15.38%)
45-54	0	1	3	0	4 (30.77%)
55-64	2	1	0	1	4 (30.77%)
65+	2	0	0	0	2 (15.38%)
Gender (male)	3	2	2	1	8 (61.54%)
Gender (female)	2	1	1	1	5 (38.46%)
Race/Ethnicity					
Caucasian	5	3	2	2	12 (92.31%)
Asian	0	0	1	0	1 (7.69%)
Academia Leader Type					
Department Chair	3	2	3	1	9 (69.23%)
Dean	1	1	0	0	2 (15.38%)
Alumni Relations Coordinators	1	0	0	1	2 (15.38%)
Length of Time Academia Leader has Lived in Georgia					
6 months -1 year	0	0	1	0	1 (7.69%)
1-5 years	0	2	0	1	3 (23.08%)
6-10 years	1	0	2	0	3 (23.08%)
10+ years	4	1	0	1	6 (46.15%)
Length of Time Academia Leader has Held Leadership Position					
Less than 1 year	1	1	0	0	2 (15.38%)
1-5 years	0	1	2	1	4 (30.77%)
6-10 years	2	1	1	0	4 (30.77%)
10+ years	2	0	0	1	3 (23.08%)

In Table 4.5., respective statement scores denote the factor scores of the Q sorts for the four extracted factors. Also included in the table are each statement ranking within each factor, distinguished statements in each factor that were significant and distinguish one factor from another, and consensus statements that show which statements were ranked most similarly among all four factors (shown in brackets).

Table 4.5
Factor Scores for All Skill Statements by Each Identified Factor

No.	Statements	F1	F2	F3	F4
1.	Think logically and analytically	5	4	-1	1
2.	Adapt to ever-changing communication technologies	3	-3**	1	1
3.	Use style elements appropriate for the mode of communication (e.g., humor, analogy, metaphors, body language, diagrams, etc.)	1	-1	-3	-1
4.	Bring together people from different disciplines or areas to work together on a communication-related goal/project	1	1	1	-1
5.	[Participate with the public in policy making]	-4	-5	-4	-2
6.	Persuade a target audience about the benefits of science	-3	2**	-4	-3
7.	[Use language that is appropriate for the target audience]	2	3	4	5
8.	Evaluate communication outcomes and apply knowledge to future communication efforts	-2	5**	-2	1*
9.	Identify a suitable target audience for a specific message	-1	1	-2	2
10	[Use accurate and meaningful statistics when communicating science-related information]	3	1	3	3
11.	Work under the constraints of communication-related budgets	-1	-1	-4	-2
12.	Use digital media for communicating information (e.g., social media, websites, blogs, digital photos, podcasts, etc.)	0	0	2	4
13.	Strategically plan communication-related activities	-2	-1	5**	1
14.	[Engage citizens democratically in science and technology issues]	-4	-4	-3	-2
15.	[Use traditional means of mass media to communicate information (e.g., print, TV, radio)]	-2	-2	-3	-5
16.	Exhibit self-confidence when communicating science	5	2	-1**	3
17.	Respond quickly during communication-related activities	-1	-4*	-1	5**
18.	Disseminate the same information across converging media (e.g., among different media platforms and technologies)	-2	-2	0**	3**

19.	[Conduct research for communication-related purposes (e.g., conduct a survey on a specific audience to better understand their feelings/values/etc. about a specific science topic)]	0	-2	0	0
20.	Identify and consider stakeholders' diverse communication needs, wants, and preferences	4	-1	2	4
21.	Anticipate future shifts and trends in communications	-1	-3*	0	-1
22.	Identify the purpose and intended outcome of the communication	0	5	5	0
23.	Engage in two-way dialogue with a target audience	1	0	-1	2
24.	Verbally communicate information with a target audience (e.g., give a speech, presentation)	2*	0	-2	-1
25.	Plan and execute remote communication-related projects (a remote project involves professionals working from different physical locations on a unified project)	-4	-1	0	-5
26.	Incorporate feelings with facts	-1	-5	-2	-4
27.	Navigate activist pressure related to science issues/topics	-5**	0	1	1
28.	Appear trustworthy and credible during any communication-related activity	4	4	1**	4
29.	Communicate through writing with the target audience (e.g., articles, blog posts, social media posts, etc.)	1	3	4	-4**
30.	Use stories to communicate information	-3	2	3	-4
31.	Communicate visually with a target audience (e.g., graphs, infographics, videos, pictures, etc.)	0*	4	4	-3*
32.	Quickly disseminate information regarding risk and crisis communication	2	-2*	1	2
33.	[Put up a display/exhibit to communicate information]	-3	-4	-5	-1
34.	Communicate through electronic communications to a target audience (e.g., email, e-newsletters, etc.)	0	2	2	-3**
35.	Quickly solve communication-related problems (such as correcting incorrect information that was accidentally shared, mitigating unexpected backlash from audiences, etc.)	4	3	0**	2
36.	Identify and use a diverse array of digital technologies used by target audiences	1	1	3	0
37.	Work well with teams	3*	-3**	-1	0
38.	[Create messages that are short, concise, and clear]	2	1	2	0
39.	Debate scientific/technological issues	-5	0	-5	-2

Note. The four factors (represented in this table as F1, F2, F3, and F4) were analyzed by examining which statements most represented similar and different views between each group. To indicate significance levels, distinguishing statements are indicated with *$p < 0.05$ and **$p < 0.01$. Consensus statements are bracketed.

Defining and Describing Each Factor

As previously mentioned, the crib sheet method was used to analyze the data, and four unique factors were representative of the viewpoints captured through the present study. Each factor represents a set of skills that was considered most important by the participants within each factor and is described as a specific skillset. Factor 1 was assigned the nickname Think Critically and Adapt Quickly and includes academia leaders who believe thinking logically and analytically while adapting and moving quickly during communication shifts, as well as remaining consistent in messaging content, is essential to effectively communicating science. Factor 2 was assigned the nickname Communicate Intentionally and Defend Science and includes academia leaders who place the most emphasis on presenting science in a positive manner through intentional message development while remaining trustworthy and credible during all communication activities. Factor 3, nicknamed Think Ahead and Communicate in Diverse Ways, includes participants who believe planning ahead with long-term communication purposes and goals in mind is essential to effectively communicating science. Moreover, they place the most emphasis on being able to communicate through many modes and mediums, such as storytelling and visuals. Lastly, Factor 4 was assigned the nickname Communicate Efficiently and Engage Audiences and involves participants who believe it's most important to be able to consider audiences' values, perspectives, and preferences before communicating with them. They also place much value on communicating as quickly and efficiently as possible using primarily digital and converging media.

Think Critically and Adapt Quickly (F1)

Demographics (F1)

The 5 participants that loaded significantly onto Factor 1 include three department chairs, one assistant dean, and one alumni relations coordinator, all of which ranged in age from 25 to over 65 years. The three department chairs are associated with departments that involve more hard sciences, such as pathology and biology.

Highest and Higher Ranked Skills (F1)

The participants in this factor believe the most important skills to have when communicating science involve thinking logically and analytically and exhibiting self-confidence when communicating science (S1: +5; S16: +5). “Thinking logically… [is] critical to addressing audiences in issues dealing with science. I believe [it is one of the] bedrocks of science and communication about science” (Participant 3).

Participants in this factor also place a lot of emphasis on appearing trustworthy and credible during any communication-related activity (S28: +4) and using accurate and meaningful statistics when communicating science (S03: +2), which aligns with the viewpoints of Factors 2 and 3. Moreover, they ranked quickly solving communication-related problems and adapting to ever-changing communication technologies higher in importance than did any other factor (S35: +4; S02: +4), and they place a lot of emphasis on quickly disseminating information regarding risk and crisis information (S32: +2). This indicates that these participants seek professionals who can solve problems and adapt and move quickly during communication-related activities. Moreover, they believe responding in timely manners with relevant, accurate information can convey a professional’s self-confidence and credibility. “It is critical to provide accurate data-based information and for that info to be relevant to stakeholder needs” (Participant 4).

Lowest and Lower Ranked Skills (F1)

While participants in Think Critically and Adapt Quickly do believe thinking logically and analytically is one of the most important skills, they place the least amount of emphasis compared to all other factors on strategically planning communication-related activities and evaluating communication outcomes and applying knowledge to future communication efforts (S13: -2; S08: -2). This could be because they believe professionals can acquire strategic planning skills through job experience while skills involving thought processes and interpersonal communications are more natural characteristics. Employers might seek professionals with 'natural' skills first, as these can be harder to teach while on the job (Noah & Aziz, 2020; Qizi, 2020). "I think that there are certain things (writing styles, graphic design, etc.) that can be taught and certain things (empathy, teamwork, etc.) that you just have to have. The things that you naturally have I feel are more important when considering a potential employee as you can always go back and teach them the others along the way during their career" (Participant 5). Further supporting this viewpoint, participants in this factor believe working well with teams is more important than does any other factor (S37: +3).

Contrarily, participants in this factor ranked navigating activist pressure related to scientific and technological issues and debating scientific and technological issues as the most unimportant skills (S27: -5; S39: -5), indicating that they don't think changing people's minds should be an overarching goal of science communication. "I put no emphasis on activist pressure, because activists come from religious, ethical, or moral standpoints, and it is not realistic to change any minds through science" (Participant 3). They also ranked engaging citizens democratically in scientific and technological issues, participating with the public in policy making, and persuading audiences about the benefits of science as relatively low in importance (S14: -4; S05: -4; S06: -3). Thus, these participants don't seem to place as much value on engaging audiences in ways that could result in swaying opinions, but they do emphasize remaining consistent with messaging. "While it is important to know your audience and tailor your message delivery, most of what we deliver should be consistent even if articulated in a way that may more easily connect with a group or individual" (Participant 4). However, and somewhat ironically, they do believe engaging in two-way dialogue with audiences is somewhat important (S23: +1), especially regarding the emergence of new audiences. "[Agriculture] is an extremely diverse industry and while at present dominated by seniors the demographic is changing. Engaging a younger audience will be critical and the process should be iterative and dynamic." Nonetheless, participants in this factor overall believe future professionals should be able to think about communication shifts, messaging content, and audiences in a critical manner, considering the advantages and disadvantages of various communication initiatives and adapting quickly to achieve communication goals.

Communicate Intentionally and Defend Science (F2)

Demographics (F2)

Three participants loaded significantly onto Factor 2, and they include the college dean and two department chairs. The department chairs are associated with departments that involve more soft sciences, such as communication and leadership. Their ages range from 35-64.

Highest Ranked Skills (F2)

These participants believe evaluating communication outcomes and applying them to future communication efforts and identifying the purpose and intended outcome of the communication are the most important skills (S08: +5; S22: +5). They also believe identifying a suitable target audience for a specific message as relatively high in importance (S09: +1).

Therefore, they strongly value being intentional when developing and delivering specific messages and thinking logically and analytically (S01: +4) about the outcomes of the delivered messages.

Additionally, more so than does any other factor, participants in Communicate Intentionally and Defend Science believe persuading a target audience about the benefits of science and debating scientific and technological issues (S06: +2; S39: 0) are relatively high in importance, indicating that they value professionals who can effectively defend the advantages of, and complex processes involved in, science. This might be why they place more emphasis on appearing trustworthy and credible during any communication-related activity (S28: +4), as exuding credibility is a key component to effectively delivering information in a manner that persuades audiences to behave in certain ways or align with certain beliefs (Cian et al., 2020).

Moreover, from a more technical standpoint, participants in this factor believe communicating visually with a target audience (e.g., graphs, infographics, videos, pictures, etc.) is relatively high in importance (S31: +4), which is similar to the viewpoint of Factor 3. Additionally, participants in Communicate Intentionally and Defend Science place more emphasis on using stories to communicate science (S30: +2) more than does Factor 1 or Factor 4. They may be more inclined to seek professionals who can use stories, visuals, and other forms of communication to craft persuasive narratives.

Lowest and Lower Ranked Skills (F2)

Additionally, participants in this factor believe participating with the public in policy making and incorporating feelings with facts are the most unimportant skills (S26: -5; S26: -5), and they place the lowest amount of emphasis compared to any other factor on conducting research for communication-related purposes (e.g., conduct a survey on a specific audience to better understand their feelings/values/etc. about a specific science topic) (S19: -2). Thus, participants in Communicate Intentionally and Defend Science primarily value professionals who can intentionally craft messages for specific audiences that effectively defend the necessity of science in agriculture and exude credibility when initiating and executing communication activities. "… The focus is on the 'what' and 'how' information is communicated; and the trust of the communicator" (Participant 8). Moreover, it's important to note that all three participants in this factor mentioned how they selected the most important skills based on translatable qualities. "I selected the foundational skills of strategic communication that will prepare employees to communicate science effectively, regardless of medium/technology or the specific scientific topic. If they master these, they will be able to adapt to employer needs" (Participant 6). In other words, certain communication skills are essential to have no matter what the context or situation of the intended message is, and they can be translated into effective science communication. The essential skills according to the participants in this factor are intentionally crafting messages and upholding the integrity and importance of science through those messages.

Think Ahead and Communicate in Diverse Ways (F3)

Demographics (F3)

The three participants that significantly loaded onto Factor 3 include department heads from departments that involve more hard sciences, such as soil sciences and food technology. Their ages range from 45-54.

Highest and Higher Ranked Skills (F3)

They place the most emphasis on strategically planning communication efforts, as they ranked strategically planning communication-related activities higher than did any other factor (S13: +5). They also believe that identifying the purpose and intended outcome of the communication is key to strategic planning (S22: +5), similar to participants in Communicate Intentionally and Defend Science. However, a distinguishing viewpoint of the participants in this factor is that they place a higher relative emphasis on considering long-term goals and thinking ahead, such as anticipating future shifts and trends in communications (S21:0) "Effective planning was primary (+5) ranking, which would allow for evaluation and modification of messaging over a longer term" (Participant 10). "If we are to effectively address the current and future challenges facing agriculture, we need to start with a solid communication plan. We do not have the time for anything else" (Participant 11). This can also lead to message consistency, as Participant 11 stated, "In my experience, being consistent with your message is the most important part of communication. This means carefully thinking about the purpose and what your goals are."

Another distinguishing viewpoint of the participants in this factor is that they believe communicating through multiple modes and mediums is essential. For example, participants believe more so than those in any other factor that communicating through writing with a target audience (e.g., articles, blog posts, social media posts, etc.), communicating visually with a target audience (e.g., graphs, infographics, videos, pictures, etc.), and using stories to communicate information are all relatively very important skills (S29: +4; S31: +4; S30: +3). They also place relatively high value on using a diverse array of digital technologies and communicating through electronic communications (e.g., email, e-newsletters, etc.) (S36: +3; S34: +2). Moreover, they believe planning and executing remote communication-related projects (a remote project involves professionals working from different physical locations on a unified project) (S25: 0) is more important than did participants in other factors. Thus, these participants seek professionals who have a lot of technical skills and understand how to engage in the use of multiple communication mediums, primarily mediums that are suitable for digital media. They don't place as much value on orally communicating information (e.g., give a presentation, speech, etc.), using traditional means of mass media, or putting up a display or exhibit to communicate information (S24: -2; S15: -3; S33: -5).

Lowest and Lower Ranked Skills (F3)

Interestingly, participants in this factor place the least amount of emphasis than does any other factor on exhibiting self-confidence during any communication-related activity and thinking logically and analytically (S16: -1; S01: -1), and they ranked appearing trustworthy and credible during any communication-related activity as relatively low in importance (S28: +1). This isn't to make the point that they don't value exuding credibility and confidence, or the ability to think logically and analytically about communications, but rather that these participants more heavily value diverse strategic planning and technical skills that result in consistent messaging content. They seek professionals who can work and communicate well with other professionals and disciplines (S04: +1), as this can help foster the development and dissemination of consistent messages. "I tended to weight the planning and team-based skills higher since I have always worked in large collaborative groups, and it is very important to know that everyone is on the same page and providing the same message" (Participant 11).

Communicate Efficiently and Engage Audiences (F4)

Demographics (F4)

The final factor consists of two participants, one of which is a department chair of a department associated primarily with the hard science and one of which is an alumni relations coordinator. They ranged in age from 35-64 years.

Highest and Higher Ranked Factors (F4)

These participants believe more so than do participants in other factors that responding quickly during communication-related activities is the most essential skill to have when communicating science (S17: +5). Similar to the viewpoint of Think Critically and Adapt Quickly, these participants also strongly value quickly solving communication-related problems and quickly disseminating information regarding risk and crisis communication (S35: +2; S32: +2). They value adapting and moving quickly during communication-related activities, but more so than participants in other factors they value communicating efficiently, such as disseminating the same information across converging media (e.g., among different media platforms and technologies) (S18: +3). "I based [the rankings] off of overall strategy and areas I felt would have an impact the quickest" (Participant 13). They also emphasize more so than participants in other factors the importance of using digital media for communicating information (e.g., social media, websites, blogs, digital photos, podcasts, etc.) (S12: +4). Therefore, they seek professionals who can use a diverse array of digital communication technologies (S36: 0) simultaneously, reaching multiple audiences at once and efficiently conveying a consistent and accurate message. "In today's world people expect quick access to facts, or else they will go elsewhere to get their information" (Participant 12).

Participants in this factor also believe that engaging audiences is relatively high in importance, as they ranked engaging in two-way dialogue about science with a target audience higher than did participants in any other factor (S23: +2). Similarly, they place the most emphasis overall on understanding the feelings and preferences of audiences and using language that is appropriate for them (S19: 0; S20: +4; S07: +5). Thus, they value tailoring messages to specific audiences (S09: +2). Additionally, and similarly to Factors 1 and 2, they believe appearing trustworthy and credible during any communications-related activity, exhibiting self-confidence, and using accurate and meaningful statistics when communicating science-related information are highly important skills (S28: +4; S16: +3). “Know your audience is my main recommendation for communicating effectively… We [also] need to make sure the information we convey is accurate and the audience trusts the source” (Participant 12). Lastly, participants in Communicate Efficiently and Engage Audiences emphasize more so than participants in any other factor the importance of participating with the public in policy making and engaging citizens democratically in science and technology issues (S05: -2; 14: -2). “We need professionals in the workplace that are skilled with how to communicate and help drive policy that affects those in the agricultural industry” (Participant 13).

Lowest and Lower Ranked Skills (F4)

However, these participants place very little emphasis on incorporating feelings with facts (S26: -4). “Adding feelings could harm the effectiveness of our message. Sticking to facts ensures the info is trustworthy and we don't include issues that could be based on political, personal, or other biases” (Participant 12). Additionally, unlike Factor 3, participants in this factor place less emphasis on technical skills, but they place the most emphasis on putting up a display or exhibit to communicate science (S33: -1). However, time constraints might be a barrier to this communication form. “A display/exhibit could help, but in some cases, there is no time to prepare one” (Participant 12).

Therefore, overall participants in this factor believe being able to efficiently engage audiences in various ways to support decision making, as well as to do so in a consistently credible manner, are the most important science communication skills for future professionals to have within the agriculture industry.

Shared Viewpoints Among All Factors

While there are many distinguishing viewpoints among each factor, there are a few viewpoints that are shared among all four factors. For example, all factors believe using language that is appropriate for the target audience is relatively highly important (S07: +2, +3, +4, +5), thus indicating that academia leaders collectively value the skill of discerning when to use scientific jargon or more simplistic, clear messages to effectively communicate science. Along the same lines, participants in all four factors believe that creating messages that are short, concise, and clear is a relatively important skill (S38: +2, +1, +2, 0). They collectively place emphasis on keeping messages digestible and understandable whether the target audience is a group of expert scientists or a group of nonexpert citizens. Additionally, participants in all four factors believe using accurate and meaningful statistics when communicating science-related information is very important (S10: +3, +1, +3, +3), as this helps ensure credibility and trustworthiness. Participants from every factor mentioned how providing accurate information and exuding credibility is key to effective science communication.

Participants in all four factors are relatively neutral regarding the importance of conducting research for communication-related purposes (e.g., conduct a survey on a specific audience to better understand their feelings/values/etc. about a specific science topic) (S19: 0, -2, 0, 0). Moreover, they do not place much value on engaging citizens democratically in science and technology issue or participating with the public in policy making (S14: -4, -4, -3, -2; S05: -4, -5, -4, -2). While participants in Factor 4 placed the most emphasis on both, it was still a relatively low amount of emphasis compared to all other skills. Finally, participants in all four factors believe using traditional means of mass media to communicate information (e.g., print, TV, radio) is not a very important science communication skill (S15: -2, -2, -3, -5). As

Participant 7 stated, “One challenge for traditional sources of information is maintaining relevancy in an increasingly noisy environment.”

Discussion, Recommendations, and Conclusion

Q methodology was used in this study to provide detailed and nuanced insights into how academia leaders view the importance of various science communication skills and reveal the most prominent influential factors regarding academia leaders’ perceptions of science communication within the agriculture industry. In the present study, four general viewpoints were defined and described to exemplify the perspectives of leaders in UGA’s CAES across various roles and departments. Importantly, the results of this study are only directly applicable to the participants and the departments they represent, but the results are nonetheless meant to inform a detailed picture of the attitudes and perceptions that this population carries toward various science communication skills within the context of Georgia’s agriculture industry. Through exploring these attitudes and perceptions depicted through the distinct viewpoints captured in this study, we aim to discuss how these findings can inform the development of and enhance existing science communication curricula at the university level, as well as contribute to more effective science communication within the agriculture industry.

The shared viewpoints among the four factors reiterate findings from other studies in that using language that is appropriate for a target audience is one of the most consistently cited essential skills in the literature regarding effective science communication, and this is a skill that’s especially important within the viewpoint of Communicate Efficiently and Engage Audiences. However, participants in the present study did not seem to emphasize the importance of identifying suitable target audiences as much as other scholars have emphasized in previous studies (Kurtzo et al., 2016; Mercer-Mapstone & Kuchel, 2017; Shivni et al., 2021). Academia leaders in this study did commonly mention the importance of learning about and considering audiences both explicitly and inherently in post-survey comments, but other skills took precedence over this skill. For example, thinking logically and analytically, as well as considering communication purposes and evaluating communication outcomes for improving future communication efforts, were the skills at the forefront of the present study, especially regarding the viewpoints of Think Critically and Adapt Quickly (F1), Communicate Intentionally and Defend Science (F2), and Communicate Efficiently and Engage Audiences (F4).

These viewpoints align with other examples in the literature, such as how an evidence-based science communication course required students to develop and defend logical, coherent arguments and engage in analytical thought processes (Oliveira et al., 2021). In another study, which involved interviewing multiple types of experts (including educators) within the agriculture industry about their perceptions of importance agricultural communication skills, it was found that "strategies and tactics must guide message dissemination, and the success of the message is determined by the evaluation of the message delivery" (Kurtzo et al., 2016, p. 22). Thus, it's recommended that university-level science communication curricula involve objectives that focus on developing strong analytical skills, as well as skills relating to strategically planning communication activities through the application of analytical skills. Strategic planning skills could involve identifying a specific communication purpose and intended outcome, as well as identifying and using language that is appropriate for the target audience.

Furthermore, academia leaders in the present study, particularly in Think Critically and Adapt Quickly, strongly value the ability to exhibit credibility and confidence through providing accurate and relevant information when communicating science within the context of agriculture, an aspect of science communication that has become more and more prevalent over the past few decades in studies regarding effective science communication (Doerfert & Miller, 2006; Intemann, 2022, 2023; Kurtzo et al., 2016). This could be because there is so much opportunity for distorted information to negatively impact truthfully evidence-based scientific messages, especially with the rise of digital and social media (Chowdhury et al., 2023; Stroud, 2019).

To help foster trust between professionals within the agriculture industry and various audiences, academia leaders in the present study believe using accurate and meaningful statistics is important, but this specific skill has not been established as very important, or even a necessary skill at all, in previous studies. Nonetheless, understanding how to reason and communicate in the language of statistics (Parke, 2008) might become more essential to effectively communicating science within the agriculture industry, especially considering the rising importance of Big Data in the most current landscape of the agriculture industry (Bongomin et al., 2020; Liu et al., 2020). Moreover, academia leaders in the present study were neutral in regard to the importance of conducting research for communication-related purposes, but this might be because conducting research is time-consuming and isn't necessarily the responsibility of all professionals within the agriculture industry. For example, employers might expect outreach or communications specialists within an agriculture organization to be able to research audience demographics and characteristics, but they might not expect that of scientists within the same organization (Metcalfe, 2019).

Also, academia leaders in the present study, particularly in Think Critically and Adapt Quickly and Engage Audiences and Communicate Efficiently, believe crafting messages that are short, concise, and clear is an essential skill to have when communicating science, which aligns with previous research (Intemann, 2023; Kurtzo et al., 2016; Noar & Austin, 2020; Oliveira et al., 2021). Messages need to cut through the clutter of information overload and be minimal in scientific jargon (Dudo et al., 2021; Kurtzo et al., 2016), and they need to be able to fit into multiple media forms, as “mobile communication technologies have facilitated [the agriculture industry’s] audiences’ increasing demand for near-instantaneous information available through multiple delivery formats” (Doerfert & Miller, 2006, p. 11; Kurtzo et al., 2016). The convergence of media provides opportunity to disseminate to-the-point yet consistent messages in many places and thus to many audiences at once (Bongomin et al., 2020; Doerfert & Miller, 2006). This, however, contradicts the idea that messages need to be tailored to specific audiences. Thus, strategizing is of key importance, as being able to discern the intended outcomes of a message will inform how and to whom the message is disseminated (Doerfert & Miller, 2006; Dudo et al., 2021; Intemann, 2023; Worley et al., 2022). Thus, it’s recommended that science communication curricula at the university level involves learning how to identify and use suitable language for specific target audiences, as well as how to use multiple media platforms and technologies at once and/or for specific reasons and contexts. Again, strategic planning and analytical skills should be developed.

Additionally, academia leaders in the present study, primarily in Communicating Efficiently and Engaging Audiences, find to some extent the skill of engaging audiences in two-way dialogue about science important, which slightly aligns with previous findings. For instance, it was found in a few studies that North American-based science communication trainers continue to emphasize knowledge building as a core component of curricula (Besley et al., 2016; Dudo et al., 2021; Yuan et al., 2017). However, this was not a heavily prioritized skill in the present study. Moreover, engaging citizens democratically in scientific and technology issues and engaging with the public in policy making were a few of the least prioritized skills in the present study. This aligns with previous research in that the “knowledge deficit model”, in which it's assumed that the scientist knows best (has the most accurate information) and needs to fill the knowledge gap for the public, who presumably knows little, has commonly taken precedence over other models regarding science communication. However, any scholars have argued that scientists may need to consider communication efforts and objectives that go beyond just disseminating factual knowledge about science to various audiences (Besley et al., 2018; Dudo et al., 2021; Metcalfe, 2019; Shivni et al., 2021). Knowledge building, as opposed to only knowledge sharing, along with identifying and applying useful engagement strategies to foster dialogues and participation between professionals and the public could be more effective in terms of gaining and maintaining buy-in from various stakeholders (Besley et al., 2018; Besley et al., 2016; Metcalfe, 2019; Yuan et al., 2017).

Furthermore, theory and practice aren't always in perfect alignment (Arteaga et al., 2023; Metcalfe, 2019). Even popular and well-supported theories come with their disadvantages and weak points (Brossard & Lewenstein, 2009; Metcalfe, 2019; Reincke et al., 2020). For example, the Lay Expertise Model, in which the public's knowledge (e.g., indigenous knowledge of land conservation) informs and influences knowledge that's acquired through science-oriented institutions, can be criticized for not fully considering or giving sufficient merit to the scientific rigor of, for example, a research institution at a university. Along the same line, democratically engaging the public on scientific and technological issues can be criticized for how its primary focus isn't on increasing public understanding but rather on addressing politics (Brossard & Lewenstein, 2009). Nonetheless, regarding the KE framework, many communities and groups are underrepresented in Kes, as knowledge is often shared with only the people who can adequately access it (Berkes & Gaetani, 2023; Dudo et al., 2021; Unger, 2022). In other words, "science communication practices construct a narrow public that reflects the shape, values, and practices of dominate groups at the expense of the marginalized" (Dawson, 2018, p. 784). In other words, science-oriented institutions often overlook the feelings, values, and knowledge bases of underrepresented audiences and thus rarely include them in science communication efforts, such as co-creating knowledge with them or tailoring messages for them (Canfield et al., 2020; Judd & McKinnon, 2021).

Implications and Recommendations for Science Communication Curricula at the University Level

While there are varying viewpoints among leaders in UGA's CAES regarding the importance of science communication skills within the agriculture industry, participants mentioned how all skills used in this study are arguably important in one way or another. Most participants mentioned how they had difficulty ranking any of the skills as 'less important' than others. However, this study identified which skills are prioritized by leaders with differing roles and from differing departments within UGA's CAES, and thus with differing associations to Georgia's agriculture industry. Therefore, this study illuminated specific skillsets that may need to be more intensely focused on in science communication training programs, such as university-level curricula. This is not to say that other skills that weren't necessarily prioritized should be ignored in curriculum development, but rather they should be emphasized to a lesser extent. Furthermore, science communication curricula could involve the development of skills that academia leaders most prioritize along with the skills that agriculture industry leaders most prioritize, thus balancing the curricula in practice and theory (Mercer-Mapstone & Kuchel, 2017). Therefore, it's recommended that the findings from this study be used to guide collaboration efforts between the agriculture industry and the university to inform science communication curricula.

It's also important to consider how ‘effective’ science communication has different meanings in different scenarios, as different goals and even different organizations might regard different outcomes as successful, thus requiring different science communication skills from professionals (Intemann, 2022, 2023). For example, if the goal of an organization is to persuade policymakers to make decisions regarding various agricultural legislation, it might make more sense for professionals within that organization to have stronger debate and persuasion skills, as well as be able to effectively engage citizens in public policy making (Priest, 2013). Along the same line, specific roles require specific skills. A communications coordinator, for instance, might need to have more skills regarding engaging audiences in two-way communication as opposed to, for example, a biological scientist (Flynn, 2014). Nonetheless, communication skills in general, no matter whether in regard to science, are highly valued among all professions and professionals (Kumar & Lata, 2011). Having strong interpersonal communication skills, also referred to as ‘people’ skills, allows for collaboration, growth, and positive outcomes for companies within every industry (Warrner, 2021).

Overall, based on the insights from academia leaders within UGA’s CAES we recommend that science communication curricula at the university level involve objectives that focus on developing strong analytical skills, as well as skills relating to strategically planning communication activities through the application of analytical skills. Strategic planning skills could involve identifying a specific communication purpose and intended outcome, as well as identifying and using language that is appropriate for the target audience. It’s also recommended that objectives focus on building self-efficacy, as this can result in more confident science communicators (Hendrix & Morrison, 2018), as well as developing strong statistical skills and being able to use statistics in meaningful ways when communicating to various audiences. For more specific programs, implementing objectives that focus on developing strong research skills for understanding the dynamics and characteristics of target audiences would be beneficial. Moreover, an emphasis on learning how to use multiple media platforms and technologies at once and/or for specific reasons and contexts would be beneficial. Along the same line, developing writing skills, learning how to develop and use visuals, and learning how communicate through e-communications could help future professionals learn how to communicate in diverse ways. Developing interpersonal communication skills that allow future professionals to grow as team workers should also be included as an objective. Overall, skills that involve strategizing, intentionally developing messages, and engaging audiences should be more emphasized than technical skills, such as communicating through writing, communicating orally, or setting up a display/exhibit.

Furthermore, while academia leaders did not emphasize engaging audiences in two-way dialogue, participatory policy making, etc., it is still recommended based on previous literature that scientists and other professionals within the agriculture industry do begin placing more value on engaging audiences, particularly underrepresented and historically marginalized audiences, as this could help foster more knowledge sharing and building and potentially result in new scientific and technological innovations and possibly even new agricultural sectors and industries. In other words, training professionals to be more cognizant of inclusivity and engage in more innovative science communication efforts could allow for the agriculture industry to tap into unexplored areas of Georgia's KE and further expand it. Examples of projects and activities that exemplify this concept include the Biota Project (Cheng et al., 2018), citizen science initiatives (Ebitu et al., 2021; Mahajan et al., 2020), the Inclusive Science Communication Symposium (Canfield et al., 2020), and the Cornell Lab of Ornithology (Lopez-Fretts, 2020).

Limitations and Recommendations for Future Research

When considering the implications of this study for future research, the KE framework along with the UIC model was a useful conceptual framework regarding the development of a big-picture perspective on how knowledge flows among actors on a multidimensional level. For instance, scientific knowledge can flow from researchers to agriculturalists to consumers, just as knowledge regarding what the most important science communication skills are can flow from academia leaders to future professionals to the agriculture industry. Through effective communication and adequate ICT infrastructure, this flow of knowledge has the potential to increase innovation and economic expansion (Unger, 2022). The novel contribution this study makes to existing literature is that it's the first to apply the KE and UIC conceptual framework to a Q methodological study, and it's the first to identify nuanced science communication skill prioritizations among academia leaders for future professionals to have within Georgia's agriculture industry. The insights from this study are intended to guide decision-making processes during science communication curricula development.

As evidence-based and balanced curricula require both theoretical and practical underpinnings, one recommendation for research moving forward includes examining the viewpoints of leaders within Georgia's agriculture industry. Moreover, this would provide a holistic and complete basis for academia leaders to engage in conversation with industry leaders, thus allowing for true UIC. Also, this study only focused on perspectives in relation to Georgia's agriculture industry and UGA's CAES, thus findings aren't generalizable to agriculture industries or universities in other states—however, applying the conceptual framework as well as the Q set used in this study to similar research efforts in other states and universities could be beneficial. Also, a very select group of individuals were selected as participants, as they were all department chairs, deans, or alumni relations coordinators. Therefore, conclusions from this study are only generalizable to the individuals in this group, and future research could focus attention on the perspectives of other groups such as underrepresented stakeholders (Canfield et al., 2020).

Furthermore, the application of Q methodology in this study did help gain nuanced perspectives among a target participant group, but there are other methods and methodologies (e.g., interviews, focus groups, Delphi methods, and surveys) that could be used to achieve the same research objectives but with differing avenues of data interpretation and results. Therefore, future research could involve conducting a study with the same objectives as the present study but using a different method or methodology. Additionally, some possible or relevant skills could've been excluded from the Q set, and the wording of skills could have influenced participants' sorting processes. Thus, future research could involve further optimizing of the Q set. Similarly, QMethod Software proved to be difficult to use at times for academia leaders, and simple challenges that involve software malfunctions or glitches can influence the integrity and depth of data collection. Therefore, future research might involve paper-based, face-to-face Q sorts that don't involve technology or other software and/or web-based data collection programs.

Additionally, the agriculture industry and the communication landscape are constantly evolving (Alam et al., 2023; Hadlington et al., 2023; Moser, 2020). While the present study is future-oriented (since some skills were 'harvested' from articles discussing the future of the agriculture industry) it only applies to a specific time period. Continuous research and UIC is needed to ensure the development and implementation of consistently up-to-date and relevant science communication practices and training.

Finally, one study sought to identify key characteristics of current science communication programs based in North America, and the characteristics under question included the following: who is receiving science communication training, what are scientists being trained to do, how much strategy is present in the training, to what extent does the training enact behavior, and how do trainers know if their training works? While this framework was originally applied to science communication training programs primarily outside of academia, it is still highly recommended for use in future research that aims to address any content-related and logistical aspects of university-level science communication curricula development, as well as evaluation of the characteristics and effectiveness of any university-level science communication curricula that is hereafter implemented. Additionally, it's recommended to use the outlines and lesson plans of an extant science communication curriculum, particularly one developed by Kelp and Hubbard (2021), to act as a template for the outlines and lesson plans of future curricula at UGA's CAES while adapting the nuanced skillsets found in this study (Kelp & Hubbard, 2021).

Conclusion

The purpose of this study was to identify nuanced perspectives regarding the importance of various science communication skills from leaders in UGA's CAES to help inform science communication curricula at the university level and to contribute to more effective science communication practices within Georgia's agriculture industry. This study was one of the first to apply the KE framework and the UIC model to a Q study investigating the perspectives of academia leaders in UGA's CAES, and future studies should build from this by using the novel conceptual framework or a combination of other frameworks such as knowledge flows, spillovers, and externalities (Karlsson & Gråsjö, 2021) and various curriculum development models (Bhuttah et al., 2019) to further explore academia leaders' nuanced perspectives regarding skill importance through Q methodology.

Q methodology allowed for the discovery of four primary viewpoints, or prioritized skillsets, among academia leaders, which were Think Logically and Adapt Quickly (F1), Communicate Intentionally and Defend Science (F2), Think Ahead and Communicate in Diverse Ways (F3), and Communicate Efficiently and Engage Audiences (F4). While these viewpoints are distinct in certain ways, they also contain much overlap among them. This indicates that there are specific skills that should be more heavily emphasized within certain programs while other more broadly applicable skills should be heavily emphasized across all science-based programs. Thus, the development of teaching resources that guide science communication trainers should take into consideration academia leaders' input.

In conclusion, the definition of effective science communication and the identification of key skills that result in effective science communication within the agriculture industry are more or less indistinct and non-concrete, but the use of Q methodology is a promising opportunity to continue defining and exploring science communication in the agriculture industry in a nuanced, detailed manner (Watts & Stenner, 2012). Moreover, participants who engaged in the activities of this study reported that the Q-sort exercise forced them to think critically about what effective science communication both looks like and requires within their respective department foci, which resulted in the collection of well-though-out and meaningful data. Hopefully this study will inspire future studies to focus on academia perspectives in a novel way and encourage the combination of both qualitative and quantitative measures to explore the most necessary skillsets for the most effective science communication within the agriculture industry.

CHAPTER FIVE: DISCUSSION, RECOMMENDATIONS, AND CONCLUSION

Introduction

Many sciences are foundational to agriculture, such as food science, crop and soil science, veterinary science, entomology, horticulture, and others (Weiner, 2003). Agriculture has also been considered the practical meeting place of science and technology (Hays, 2007). This has become especially evident when considering the advancement of agriculture over time (Alam et al., 2023; Doerfert & Miller, 2006; Liu et al., 2020). Numerous scientific and technological innovations have coincided with the improvement of land management, higher crop yields, better food preservation, and a more sustainable agri-food system (Brown et al., 2019; Delgado et al., 2019; Fess et al., 2011; Khanna et al., 2023; Kumar et al., 2023). Moreover, these innovations could greatly contribute to successfully and sustainably feeding a growing population, which is projected to require a 60%–100% increase in food production worldwide by 2050 (Alfred et al., 2021; Bhat & Huang, 2021; McFadden et al., 2023; Monteiro et al., 2021).

However, as these innovations become more and more complex within the agriculture industry, more effective science communication will be required to maintain stakeholder support and buy-in for sustainable and precision agriculture (Intemann, 2023; Monteiro et al., 2021; Ruth et al., 2018). This has become increasingly difficult to accomplish as numerous communication challenges have emerged along with the rise of mass, digital, and social media (Aïmeur et al., 2023; Hadlington et al., 2023; Lwin et al., 2023). In fact, public trust in science and agriculture has been decreasing, resulting in agricultural legislation that hurts producers, a lack of funding in agricultural research, and consumers refusing to buy certain agricultural products (Chowdhury et al., 2023; Diekman et al., 2023; Henderson et al., 2020; Stroud, 2019). Therefore, there is a need for more effective science communication within the agriculture industry.

One way to move forward in enhancing effective science communication within the agriculture industry is by improving science communication training and curricula at the university level, as many scientists and other professionals who work within the agriculture industry have a degree from a university but lack formal communication training (Simis et al., 2016; Washburn et al., 2022). Furthermore, the way in which information is shared about science and agriculture has changed over time—among producers, scientists, consumers, and other stakeholders (Chowdhury et al., 2023; Ismagilova et al., 2020; Nesmith, 2020; Rust et al., 2022)—and this should be addressed in current science communication curricula (Fähnrich et al., 2021). Another factor that influences science communication curricula is that universities often base their curricula on scholarly theories rather than work-based experience (Doerfert & Miller, 2006; Ellahi et al., 2019; Kemp et al., 2021; Mercer-Mapstone & Kuchel, 2017), which is problematic because professionals need more work-based experience and knowledge to more intentionally and effectively serve the institutions at which they are employed (Kemp et al., 2021; Mercer-Mapstone & Kuchel, 2017).

Therefore, the present studies address the need for more evidence-based and balanced science communication curricula at the university level through the application of the KE at the state level, the University-Industry Collaboration (UIC) model, and Q methodology. Q methodology was used to capture the nuanced viewpoints regarding which skillsets are most prioritized for future professionals to have when communicating science within Georgia's agriculture industry. The KE framework allows for a big-picture conceptualization of how knowledge flow among different actors, such as innovation systems and a skilled and well-educated population, can allow for economic growth through scientific and technological innovation (Powell & Snellman, 2004; Unger, 2022). Additionally, the UIC model allows for capturing scholarly, theory-based ideas as well as practical, work-based ideas to inform the development of a balanced science communication curriculum. As this model is centered on collaboration, conversation is required between the university, specifically academia leaders within UGA's CAES, and the agriculture industry, specifically industry leaders within Georgia's agriculture industry. The remainder of this chapter discusses the main findings from these studies by comparing industry and academia leaders' perspectives to inform effective science communication curricula at the university level. This chapter also presents key limitations and suggestions for future research.

Discussion

According to the findings of these studies, there are multiple aspects of science communication skills that industry and academia leaders agree upon. For example, in the first study the factor on which the most participants significantly loaded was Strategize on a Budget (F1), and these participants most heavily emphasized the importance of strategically planning communication efforts. This is identical to the viewpoint of participants in the second study who significantly loaded onto Think Ahead and Communicate in Diverse Ways. However, almost all factors between both studies included participants who value strategic planning to some extent, as factors such as Communicate Intentionally and Defend Science (F2) in the second study involves participants who most value identifying the purpose and intended outcome of a message as well as evaluating communication outcomes and applying them to future communication efforts. Similarly, Empathize with Audiences and Leverage Communication Technology (F2) in the first study involves participants who strongly value identifying a suitable target audience and considering stakeholders' diverse communication needs, wants and preferences. While many of these skills don't explicitly use the word 'strategy' in them, they are still components of strategic planning. Moreover, this aligns with previous literature in that experts from many fields consider strategic planning as an essential component of effective science communication (Kurtzo et al., 2016; Metcalfe, 2019; Oliveira et al., 2021).

On a similar note, learning about and understanding audiences was also considered a relatively highly prioritized skill among participants in multiple factors in both studies, such as Strategize on a Budget (F1), Empathize with Audiences and Leverage Communication Technology (F2) and Exude Credibility and Communicate Quickly (F3) in the first study and Communicate Efficiently and Engage Audiences (F4) in the second study. However, using language that is appropriate for a target audience was especially important to academia leaders, while conducting research on target audiences to better understand their feelings, attitudes, and perceptions about a specific science topic or issue was not deemed very important by any participants among any factors from either study. Previous literature has indicated that knowing and considering audiences is key to effectively communicating science (Kurtzo et al., 2016; Mercer-Mapstone & Kuchel, 2017).

While the ability to strategically plan communication activities was considered to be highly important to participants among all factors in both studies, some factors included participants who, even more so than strategic planning, valued appearing confident, credible, and trustworthy during communication-related activities. These factors include Exude Credibility and Communicate Quickly (F3) and Exude Confidence and Engage Audiences (F4) in the first study and Think Critically and Adapt Quickly (F1) in the first study. Interestingly, most factors in the second study (which involved academia leaders) involved participants who overall more strongly emphasized strategic planning, thinking logically and analytically, and communicating efficiently, while most factors in the first study (which included industry leaders) involved participants who overall more strongly emphasized appearing credible and trustworthy. This aspect of science communication has become more and more critical over the past few decades, most likely because of emergent communication challenges such as information and source overload (Chowdhury et al., 2023; Stroud, 2019).

Participants among all four factors in the first study very strongly emphasized creating messages that are short, concise, and clear. In the second study, participants in all four factors also found this skill to be relatively important, but they did not place as much emphasis on it as industry leaders did. Nonetheless, the majority of participants in both studies collectively placed emphasis on keeping messages digestible and understandable whether the target audience is a group of expert scientists or a group of nonexpert citizens, a component of effective science communication that has been previously cited in the literature multiple times (Intemann, 2022; Kurtzo et al., 2016; Noar & Austin, 2020). Similarly, participants in Exude Credibility and Communicate Quickly (F3) in study one and participants in Think Critically and Adapt Quickly (F1) and Communicate Efficiently and Engage Audiences (F4) in study two strongly emphasize the importance of being able to respond to audiences quickly, using communication technologies efficiently, and adapting quickly to communication shifts and trends. This is more important to academia leaders, although in the literature both academia and industry leaders have emphasized these skills more and more over the past few decades, especially considering the rise of digital media and the concept of instantaneous access to information (Chowdhury et al., 2023; Doerfert & Miller, 2006; Stroud, 2019).

Additionally, both industry leaders and academia leaders place a lot of relative value on using accurate and meaningful statistics during communication-related activities. For instance, Strategize on a Budget (F1) and Exude Credibility and Communicate Quickly (F3) from the first study and Think Critically and Adapt Quickly (F1) and Communicate Efficiently and Engage Audiences (F4) from the second study included participants who heavily emphasized the importance of using statistics to convey accuracy and credibility in science-based messages. To the best of our knowledge, this has not been found in previous literature, although it has been considered an important skill in the context of communications in general (Parke, 2008).

On a different note, more participants in the second study valued communicating through writing, visuals, and storytelling than did participants in the first study. In particular, Communicate Intentionally and Defend Science (F2) and Think Ahead and Communicate in Diverse Ways (F3) in the second study includes participants who heavily emphasized diversity in technical skills and being able to communicate through a variety of mediums and in a variety of ways. Overall, academia leaders value technical skills more so than industry leaders do, which is apparent in the content of many science communication training programs today, as curricula involves the development of more technical skills as opposed to strategic planning and analytical skills (Dudo et al., 2021).

Communicating through stories, specifically, was commonly emphasized as an effective means of sharing scientific information among participants in multiple factors in both studies. Multiple scholars have found storytelling and narratives to be effective means for communicating complex information to diverse audiences in diverse ways (Bongomin et al., 2020; Mercer-Mapstone & Kuchel, 2017; Shivni et al., 2021). Furthermore, the majority of participants among factors in both studies valued the ability to effectively use digital media, but they did not place as much emphasis on this as first being able to strategically plan messages and appear credible, trustworthy, and confident during communication-related activities. Only participants in Exude Credibility and Communicate Quickly (F3) in the first study considered using traditional forms of media to communicate information as somewhat important. In fact, academia leaders think using traditional media is the most unimportant skill for future professionals to have, and they are stronger in this belief than industry leaders are. Overall, previous literature indicates that both industry and academia are less interested in seeking or developing skills related to disseminating information through traditional forms of media (Ren et al., 2024; Xasanova, 2023; Zhang, 2021).

Importantly, almost all factors among both studies included participants who think incorporating feelings with facts is the most unimportant skill to have. This aligns with previous literature in that experts within agriculture and other industries commonly report providing accurate and factual information as the primary way to gain and maintain consumer confidence and public trust (Intemann, 2023; Metcalfe, 2019). However, other scholars have argued that incorporating more feelings with facts could result in stronger audience engagement and thus more trust in and support for science (Dudo et al., 2021; Intemann, 2022, 2023). This directly plays into engaging audiences, a skill that almost all participants among most factors in both studies deemed as most unimportant. However, academia leaders slightly emphasized the importance of engaging in two-way dialogue with audiences about science more so than industry leaders did, and this could be because communication theories, such as the participatory model of communication, is more commonly discussed within academic settings (Besley et al., 2018; Metcalfe, 2019; Reincke et al., 2020). Nonetheless, Exude Confidence and Engage Audiences (F4) in study one and Communicate Efficiently and Engage Audiences (F4) in study two involved participants who most heavily emphasized engaging audiences in two-way dialogue about science, engaging citizens democratically in scientific and technological issues, participating with the public in policy making, and navigating activist pressure. However, these factors had the fewest participants load significantly onto them, which is reflected in previous literature in that audience engagement is rarely incorporated into science communication curricula (Dudo et al., 2021). Moreover, in regard to navigating activist pressure and debating scientific issues and topics, most participants believed it was not the agriculture industry's job to convince people to change their personal values, beliefs, or ideologies. Only a few participants, particularly in Exude Credibility and Communicate Quickly (F3) in the first study and Communicate Intentionally and Defend Science (F2) in the second study, strongly believed that the feelings and attitudes of audiences do matter and have implications that should be considered appropriately.

Finally, one of the most distinguishing viewpoints among factors in both studies involves an emphasis on working within the constraints of budgets. Participants in Strategize on a Budget (F1) in the first study very heavily emphasized this skill, and participants in other factors in the first study also emphasized this more heavily than did participants in any of the factors in the second study. In fact, academia leaders indicated that they believe a lot can be accomplished communication-wise with small budgets. However, participants in the first study, particularly in Strategize on a Budget (F1), indicated that being able to use resources (which are already extremely limited) as efficiently and effectively as possible is a crucial skill for future professionals to have within the agriculture industry. This aligns with previous literature in that budget constraints can hinder innovative science communication efforts (Entradas et al., 2020; Ihm & Kim, 2021). While the effectiveness of budget allocations are highly understudied in the context of agricultural institutions, it’s evident that resources, such as funding, can be limited and limiting, especially at nonprofits and commodity organizations (Kohn & Anderson, 2022; Suh, 2022). Importantly, all but one of the six participants in Strategize on a Budget were associated with a non-profit or commodity organization.

Limitations and Recommendations for Future Research

These studies involve numerous implications for future research. For example, applying the KE framework along with the UIC model as a conceptual framework allows for a big-picture perspective on how knowledge flows among actors on a multidimensional level, such as scientific knowledge flowing from researchers to future professionals to citizens or knowledge regarding important science communication skills flowing from industry leaders to academia leaders to future professionals. The flow of knowledge, which requires effective communication and adequate ICT infrastructure through which effective communication can occur, has the potential to ultimately increase innovation and thus economic expansion (Unger, 2022). The novel contribution this study makes to existing literature is that it’s the first to apply the KE framework and UIC model conceptual framework to a Q methodological study, and it’s the first to identify nuanced science communication skill prioritizations for future professionals to have within Georgia’s agriculture industry, specifically. Thus, the insights from this study are intended to guide decision-making processes during science communication curricula development at the university level.

While the first study focused on capturing perspectives from leaders within Georgia’s agriculture industry and the second study focused on capturing perspectives from academia leaders within UGA’s CAES, its findings aren’t generalizable to agriculture industries or universities in other states—however, applying the conceptual framework as well as the Q set used in this study to similar research efforts in other states and at other universities (or even independent science communication training programs) could be beneficial. Also, a very select group of individuals were selected as participants, as they were all past, current, or board members of AGL in the first study or deans, department chairs, or alumni relations coordinators from UGA's CAES. Therefore, conclusions from this study are only generalizable to the individuals within these groups, and future research could focus attention on the perspectives of other groups. For example, students' perspectives could be incorporated into the research focus, as KE can involve students within the innovation system who will enter into the skilled and well-educated population as future professionals. Their input could act as an evaluation tool for science communication training programs and curricula (Hendrix & Morrison, 2018; Mora et al., 2020). Furthermore, if more participatory models of dialogue and communication become incorporated into future communication efforts, further research might be needed regarding other (particularly underrepresented) stakeholder's perceptions of the importance of various science communication skills, or at least what effective science communication means to them (Canfield et al., 2020).

Additionally, applying Q methodology in this study helped gain nuanced perspectives among target participant groups, but there are other methods and methodologies (e.g., focus groups, interviews, surveys, Delphi methods, etc.) that could be used to achieve the same research objectives but with different results. Therefore, future research could involve conducting a study with the same objectives as the present studies but using a different method or methodology, such as focus groups in which industry or academia leaders jointly assign their own names to factors and discuss and consider with leaders from other factors the implications of their similarities and differences in viewpoints.

Similarly, QMethod Software proved to be difficult to use at times for academia leaders, and simple challenges that involve software malfunctions or glitches can influence the integrity and depth of data collection. Therefore, future research might involve paper-based, face-to-face Q sorts that don't involve technology or other software and/or web-based data collection programs. Also, there's potential that not all possible or relevant skills were mentioned in the Q set, and it's possible that the wording of skills could have influenced participants' sorting processes. Thus, future research could involve further optimization of the Q set, such as narrowing the research focus to only involve technical skills (e.g., writing, graphic design, statistical analysis, etc.) or soft skills (e.g., working well with teams, empathizing, active listening, etc.).

Finally, it's recommended to use the outlines and lesson plans of an extant science communication curriculum, particularly one developed by Kelp and Hubbard (2021), to act as a template for the outlines and lesson plans of future curricula at UGA's CAES while adapting the nuanced skillsets found in this study (Kelp & Hubbard, 2021). Furthermore, one study sought to identify key characteristics of current science communication programs based in North America, and the characteristics under question included the following: who is receiving science communication training, what are scientists being trained to do, how much strategy is present in the training, to what extent does the training enact behavior, and how do trainers know if their training works? While this framework was originally applied to science communication training programs primarily outside of academia, it is still highly recommended for use in future research that aims to address both content-related and logistical aspects of university-level science communication curricula development, as well as evaluation of the characteristics and effectiveness of any university-level science communication curricula that is hereafter implemented. Afterall, proposing the incorporation of research findings into new programs and curricula is much different than implementing them in productive ways that truly contribute to more effective science communication and the KE. Moreover, the agriculture industry and the communication landscape are constantly evolving (Alam et al., 2023; Hadlington et al., 2023; Moser, 2020). While some skills were 'harvested' from articles discussing the future of the agriculture industry (Bongomin et al., 2020; Liu et al., 2020) and results might be future-oriented, these findings of these studies only apply to the specific timeframe of the present work. Continuous research and UIC is needed to ensure the development and implementation of consistently up-to-date and relevant science communication practices and training.

Conclusion

The purpose of this study was to identify nuanced perspectives regarding the importance of various science communication skills from leaders in Georgia's agriculture industry and leaders in UGA's CAES to help inform science communication curricula at the university level and contribute to more effective science communication practices within Georgia's agriculture industry. This study was one of the first to apply the KE framework and the UIC model to a Q study investigating the perspectives of various leaders regarding important science communication skills, and future studies should build from this by using the novel conceptual framework or other frameworks such as human capital theory (Becker, 2009), knowledge flows, spillovers, and externalities (Karlsson & Gråsjö, 2021), and various curriculum development models (Bhuttah et al., 2019) to further explore and apply agriculture leaders' nuanced perspectives regarding science communication skillset prioritizations through Q methodology.

Q methodology allowed for the discovery of four primary viewpoints, or prioritized skillsets, among participants in the first study, which were Strategize on a Budget (F1), Empathize with Audiences and Leverage Communication Technology (F2), Exude Credibility and Communicate Quickly (F2), and Exude Confidence and Engage Audiences (F4). In the second study, four primary viewpoints, or prioritized skillsets, were also discovered among participants, including Think Critically and Adapt Quickly (F1), Communicate Intentionally and Defend Science (F2), Think Ahead and Communicate in Diverse Ways (F3), and Communicate Efficiently and Engage Audiences (F4). All of these viewpoints are distinct in certain ways but simultaneously contain much overlap among them, thus indicating that there are many essential skills that should be emphasized across all science-based programs, and there are some skills that might be more useful to develop for certain contexts. Thus, it would be beneficial to engage in the development of teaching resources that strategically guide science communication trainers and professors through applying industry and academia input to training programs and curricula within the context of agriculture. The present study provides a basis for the beginning of this development.

As effective science communication in the context of agriculture has still not been concretely defined, the identification of key skills that industry and academia leaders posit result in effective science communication within the agriculture industry can help contribute to a more concrete definition, and the use of Q methodology provides a promising opportunity to continue defining and exploring science communication in the agriculture industry in a nuanced, detailed manner (Watts & Stenner, 2012). Moreover, participants who engaged in this study reported enjoying the Q-sort exercises, and they acknowledged that it forced them to think critically and analytically about what effective science communication both looks like and requires within their respective fields. Overall, the aim of this work is to inspire future research to focus on a diverse array of people's perspectives regarding both science communication and necessary science communication skillsets in novel ways—both qualitative and quantitative—and to apply findings in a manner that translates into a more dynamic and inclusive flow of knowledge.

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