Biotechnology in Agricultural Education

by

Lissi Carr Chism

A dissertation submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Career and Technical Education, Doctor of Philosophy

Auburn, Alabama
December 13, 2025

Keywords: Biotechnology, Georgia, Agricultural Education, SBAE

Approved by

Jason McKibben, Chair, Assistant Professor, Curriculum & Teaching
Christopher Clemons, Associate Professor, Curriculum & Teaching
James Lindner, Professor, Curriculum & Teaching
Jillian Ford, Assistant Clinical Professor, Agriscience Ed Curriculum & Teaching
David Chapman, Adjunct Professor, Curriculum & Teaching
Adam Cletzer, University Reader, Clinical Professor, Agricultural Communications & Leadership

Abstract

This dissertation examined the integration of biotechnology within Georgia School-Based Agricultural Education (SBAE) through three interconnected studies addressing historical development, internal factors, and external factors influencing implementation. The first study utilized a qualitative historical research design, guided by Rogers' (2003) Diffusion of Innovation Theory, to analyze state and national policy documents, curriculum frameworks, and archival records. Findings indicated that Georgia functioned as an early adopter of biotechnology in agricultural education, yet curriculum standards remained outdated and misaligned with current agricultural biotechnology practices. The second study, guided by Bandura's (1986) Social Cognitive Theory and Self-Efficacy Theory (1997), employed a quantitative survey design to measure teachers' perceived importance, knowledge, and competence regarding biotechnology topics. Results revealed that teachers valued biotechnology instruction but reported moderate levels of knowledge and competence, suggesting a need for targeted professional development. The third study investigated external factors affecting implementation, including teacher resources, student characteristics, and community support. Findings showed that while administrative and technological support were available, teachers lacked adequate instructional materials, laboratory space, and time. Students preferred hands-on learning but lacked home and community support to reinforce biotechnology concepts. Collectively, these studies underscored the need for systematic curriculum revision, ongoing professional development, and stronger interdisciplinary and community engagement to ensure that Georgia's agricultural education remained rigorous, relevant, and aligned with modern biotechnology and agricultural practices.

AI Disclosure Statement

In the preparation of this dissertation, the following Artificial Intelligence (AI) tools were used: ChatGPT5 and Grammarly. These tools were used primarily for formatting, reference checking, grammar, and spelling, as well as in the form of a thesaurus. The author acknowledges full responsibility for the intellectual content of this work and has ensured that all AI-assisted sections have been reviewed and revised for accuracy and appropriate academic style. All AI-generated content was reviewed and validated for relevance, appropriateness, and accuracy before incorporation into the final document to maintain scholarly integrity of this research.

Acknowledgments

To my beautiful, incredible children, Jack & Carroline: never be afraid to pursue the journey to accomplish the goals you have set for yourself. Absolutely nothing is impossible. I love you.

“All kids need is a little help, a little hope and someone who believes in them.”
— Magic Johnson

To my husband Alex, your unwavering support and dedication as a husband and father is unremarkable. Many dream of it, but I get to live it. I can't accurately put into words how I feel. You are the best teammate, and I want you to know how much I appreciate you for never allowing me to give up on this goal that I set for myself. Together, it has been a blessing to be able to instill values of hard work, dedication, and a love for education into our children, by going through this journey with me.

To my mama and brothers, if there is one thing life has taught us, it is the fact that we ALWAYS get it done. No matter the obstacle, hurdle, or lessons being presented to us along the way, you all have always believed in me and my abilities to shine. I am forever grateful for the strength and power of determination that were instilled in me at such a young age, to carry with me on this journey through life. Your constant support and words of encouragement, along with the hugs and shared tears, I made it. I am still going, just in a new direction with you all right behind me, cheering me on.

To my grandparents, thank you would never ever be enough. A quality education was something you never let me take for granted, and I too, know, I have made you proud on this

journey. All those years in grade school, undergraduate, and graduate school you both ensured that I made it through.

To my in-laws, the chapters you all have witnessed me go through and close, are a few too many to list out, but I would be greatly remiss if I did not give some credit for the help, I received from you all. Each of you have been more than just helping hands but also the cheerleaders I needed to reach this finish line. I am forever grateful to have married into a huge, loving family. To my sister-in-law, you were the little sister I never knew I needed, and as you embark on your post-secondary educational journey, let this be a guiding light for your hopes, dreams, and goals. Believe in YOU. Find your cheerleaders. I believe in you and all of the great things to come.

To my former students, while you were only a fraction of this journey, your impact on me was huge. Never give up on your dreams and never use your trials as excuses to stay stagnant. I still and always will believe in you.

To my friends and colleagues, your encouragement, support, and advice have kept me going in the moments it got tough. All because you all believe in me and help me empower myself to be a better, me. Thank you.

Lastly, to my doctoral committee, the mentors, and professors, you each have made the biggest impact on this journey and helped me reach the finish line– specifically, Dr. Ashley Yopp Meros, Dr. Barry Croom, and Dr. Jason McKibben. I did not at first appreciate the words of wisdom from you wise owls, until it was me. Until I was knee-deep in reaching my post-secondary finish line, would I find and have a true appreciation for your guidance, leadership, and land-grant institutional values. Thank you would never be enough for the modeling, knowledge, and encouragement that you all provided. Go Dawgs & War Eagle!

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AFNR	Agriculture, Food, and Natural Resources
CTAE	Career, Technical, and Agricultural Education
DNA	Deoxyribonucleic acid
DOI	Diffusion of Innovation
FFA	The National FFA Organtization
GaDOE	Georgia Department of Education
GSE	Georgia Standards of Excellence
IBM	International Business Machines Corporation
RTTI	Rural Teacher Training Initiative
SBAE	School Based Agricultural Education
SCT	Social Cognitive Theory
SET	Self-Efficacy Theory
SPSS	Statistical Package for the Social Sciences

Chapter 1: Foreword

Introduction

> "Science and Agriculture are not separable. They have not been in the past; they are not now; and I do not expect that they ever will be in the future (Malpiedi, 1989, p. 4)."

In 1917, the Smith-Hughes National Vocational Education Act established vocational agriculture courses with funding, at the secondary level. This was recognized as what became known as high school, agricultural education classes. The curriculum that was initially established could not keep up with the ever-rapid changing technologies to incorporate into teachings during the last part of the 20th century. Biotechnology in Agriculture grew significantly in the 1970s and 1980s, and as a result such related buzz words became popular in agricultural education (Boone et al., 2006). The 1990 National Council on Vocational Education acted on the movement and made it part of the curriculum as direction was given by the National Research Council in 1988 (National Council on Vocational Education, 1990; Thompson, 2001). In 1994, the National FFA published *The National Voluntary Occupational Skill Standards for an Agricultural Biotechnology Technician,* which was created by biotechnology and industry experts to assist state agricultural education programs in developing related courses of study (National FFA Foundation, 1994; Wilson et al., 2002). As a result, the 1998 Georgia Department of Education's 2020 Vision for Agricultural Education identified biotechnology as a theme, including goals to help educators achieve the vision. The goals included opportunities to build student awareness and appreciation of biotechnology; curriculum centered around biotechnology, and experiential learning opportunities in biotechnology (Georgia General Assembly, Senate Research Office, n.d.).

In terms of students, it was studied and proven that learning about biotechnology contributed to their agricultural awareness (Chen & Raffan, 1999) and helped them to become better informed citizens to make educated decisions (National Research Council, 2012). Not only was becoming an informed citizen important as part of their education, but also as consumers of agricultural products, as they understood that the increase in sustainable food production during their lifetime, the twenty-first century, resulted from the efforts and advancements in biotechnology (National Research Council, 2009). Research provided evidence for and supported the claim that the integration of science into the agriculture curriculum was more effective for students having higher achievement than traditionally taught students (Chiasson & Burnett, 2001; Enderlin & Osborne, 1992; Hendrix et al., 2024; McKibben & Murphy, 2021; McKibben et al., 2024; Roegge & Russell, 1990; Thompson & Warnick, 2007).

For teachers, studies showed that various challenges existed in incorporating biotechnology into the high school curriculum. The first noted challenge was that it represented one of the most strenuous topics within science. Secondly, it was highly difficult for secondary science teachers to allow time for the practicality of biotechnology activities during a normal class schedule. Lastly, agricultural education teachers were more aware of how biotechnology was applied but lacked the necessary equipment and understanding of the scientific principles to make the connections for student learning, in order to effectively incorporate into their curriculum (Steele & Aubuson, 2004; Mowen, et al., 2007; Pollard, 2020). Wilson et al. (2002) indicated that teachers' confidence in teaching students' skill standards and biotechnology curriculum was higher among those who attended workshops with training in intensive hands-on agricultural biotechnology labs, thereby showing that teacher support, in-service training were crucial to integrating a curriculum that is ever-changing. Findings from neighboring Alabama teachers has indicated that teachers, regardless of their path to certification, are more likely to adopt the teaching method or style the more they are shown or taught using that style (Hancock et al., 2024). This was similar to findings that students of agriculture prefer hands on teaching and learning methods (McKibben et al., 2023).

In Georgia, students were required to complete one pathway in Career, Technical and Agricultural Education (CTAE), and/or Modern Language/Latin, and/or Fine Arts, which included a series of three courses and take an end of pathway assessment as part of the high school graduation requirements (Georgia Student Finance Commission, n.d.). This study specifically focused on Georgia's Agriscience Systems pathway within the Agriculture, Food, and Natural Resources (AFNR) career cluster. The three courses included Basic Agriculture Science (introductory and required for all AFNR pathways), Plant Science and Biotechnology, and Animal Science Technology and Biotechnology.

Researcher's Interest

The researcher, who was a third-year agricultural education teacher in 2021, was tasked with teaching two new courses: Plant Science and Biotechnology and Animal Science Technology and Biotechnology. Upon reviewing the content standards, it was noted that the content focused heavily on biotechnology techniques, concepts that had only been mentioned in an agricultural education preparation program but were rarely practiced or taught in depth. Not wanting to settle for minimum content coverage but instead to seek professional development and teacher training that would enable the implementation of more hands-on learning around these topics, the researcher enrolled in the Georgia BioEd Rural Teacher Training Initiative in 2021-2022 and participated in an advanced session in 2023. Although the program was not designed specifically for Agricultural Education teachers, the concepts and hands-on training were easily transferred to Agricultural Education curriculum. The curriculum standards presented themselves with vague wording as a means of maintaining flexibility in what teachers chose to teach; however, it appeared that, collectively, many teachers were missing the broader goal, the actual integration of techniques and applications in accordance with modern-day biotechnology. With that question and reflection, the researcher formulated the idea for further investigation and the development of this dissertation.

Framework

For this study, three frameworks were implemented to provide a unique lens on Biotechnology in School Based Agricultural Education of Georgia.

The first framework utilized in this study is Everett Rogers' Diffusion of Innovations Theory (2003). The Diffusion of Innovation Theory was defined as a five stage process, known as the Innovation-Decision Process, in which an innovation was adopted, including (1) knowledge [recognizes and understands the innovation], (2) persuasion [forms a like or dislike towards the innovation], (3) decision [takes part in furthering the understand of the innovation to accept or reject], (4) implementation [putting the innovation to practice], and (5) confirmation [reinforcing the innovation-decision or reversing the decision] (Rogers, 2003). Rogers' DOI Theory (2003) also identified five adopter categories describing how individuals adopted innovations. The categories included, (1) innovators [2.5% of a population, gatekeepers for new innovations and the risk-takers], (2) early adopters [13.5% of a population, those who reduced the uncertainty for others to adopt serving as role models], (3) early majority [34% of a population, those who adopted just ahead of the average, acted cautiously, and required evidence of success], (4) late majority [34% of a population, those who adopted after the majority, usually because they were compelled to], and (5) laggards [16% of a population, those who were last to adopt if at all due to being traditional and resistant to change]. This framework was applied in this study, particularly in Chapter 2: Historical Analysis of Biotechnology Integration in Agricultural Education in Georgia, as it provided the foundation for analyzing how biotechnology was introduced and diffused as a content area within agricultural education. Moreover, this theoretical framework facilitated the analysis of the adopter category applicable to Georgia agricultural education teachers specializing in biotechnology.

The second framework used was Albert Bandura's (1986) Social Cognitive Theory (SCT). The Social Cognitive Theory outlined four stages to the development of learning, including (1) attention, (2) retention, (3) reproduction, and (4) motivation (Bandura, 1986). Bandura (1986) also proposed a triadic relationship through the SCT between three factors: personal (one's cognitions, beliefs, emotional and biological characteristics), behavior (one's choices and actions), and environment (social and external experiences). In summary, individuals learned not only through direct experiences but also through cognitive processes and observing others. This framework was applied to investigate how agricultural education teachers acquired knowledge about and applied biotechnology topics within their classrooms.

The third framework utilized was Bandura's (1997) Self-Efficacy Theory (SET). Bandura's Self-Efficacy Theory was developed as a direct extension of his 1986 Social Cognitive Theory. SET represented an individual's belief in their capability to be succeed at a task through their actions. Specifically, it focused on four sources of self-efficacy: (1) mastery experiences [engaging in tasks until success was achieved], (2) indirect experiences [observing others succeed at a task and believing in one's ability to replicate it], (3) social experiences [receiving positive feedback, encouragement, and/or affirmation from role models], and (4) internal experiences [how one's inner voice influenced their beliefs of being capable or not]

(Bandura, 1997). This framework was applied in this study to better understand agricultural education teachers' level of confidence regarding their ability to teach biotechnology related topics.

Purpose

The purpose of this dissertation was to examine biotechnology within SBAE in Georgia. It specifically analyzed the history of biotechnology integration, the accuracy and relevance of biotechnology topics within current content standards, and teachers' internal and external factors that contributed to their success when teaching biotechnology-related topics.

Organization

This dissertation was organized into five chapters. The first chapter included the introduction to the study and established the foundation for the subsequent four chapters. The second, third, and fourth chapters were presented as separate articles but remained connected to the primary focus, biotechnology in school-based agricultural education in Georgia. The fifth and final chapter provided a summary of the findings from each article and offered recommendations for further research and practice.

Research Objectives

This study was divided into three separate but interconnected articles focusing on biotechnology within school-based agricultural education in Georgia. It began with Article One, which presented a historical analysis of the integration of biotechnology into agricultural education in Georgia. Article Two examined the internal factors that influenced teachers' success in teaching biotechnology topics, and Article Three explored the external factors that affected their success. The research objectives listed below were used to guide the development of this study.

Article One:

1. What is the history of biotechnology integration of ag ed in Georgia?
2. Are the current content standards accurate, relevant, and necessary in accordance with modern agriculture (present day)?

Article Two:

1. What are teachers' perceived importance of, personal knowledge, and competency of teaching biotechnology topics?
2. What in-service needs can be determined by the teachers' perceived importance of personal knowledge, and competency of teaching biotechnology topics?

Article Three:

1. What are teachers' barriers to teaching and information sources of biotechnology topics?
2. What resources are needed to lessen the external factors for success of teaching biotechnology in ag ed, based on the above?

Definitions

1. School-Based Agricultural Education: "prepares students for successful careers and a lifetime of informed choices in the global agriculture, food, fiber, and natural resources systems." This is achieved through the three-component model, including classroom/laboratory, supervised agricultural experiences, and FFA (National FFA Organization, n.d.).
2. Agricultural Education: systematic instruction in agriculture and natural resources in grades 9-12 with a mission to prepare people for occupations or professions in agriculture, and/or job creation and entrepreneurship, and to promote agricultural literacy (Phipps et al., 2008).

3. Biotechnology: “refers to techniques used by scientists to modify deoxyribonucleic acid (DNA) or the genetic material of a microorganism, plant, or animal in order to achieve a desired trait.” (U.S. Food and Drug Administration, n.d.).
4. Agricultural biotechnology: is a range of tools, including traditional breeding techniques, that alter living organisms, or parts of organisms, to make or modify products; improve plants or animals; or develop microorganisms for specific agricultural uses.” (U.S. Department of Agriculture, n.d.).
5. Agricultural literacy “is the awareness and understanding [of] food, fiber, natural resources, and animal health and its relationship to the public and environment.” (Clemons, et al. 2018, p. 248.)
6. Competence is defined as knowledge, skills, abilities and other characteristics to carry out a task (Dooley & Lindner, 2002; Harder, et al., 2013; Lindner, et al. 2001)
7. Georgia Standards of Excellence: provide a structured and consistent framework designed to prepare students with the knowledge, skills, and competencies necessary for success in postsecondary education and the modern workforce (Georgia Public Broadcasting, n.d.).
8. National FFA Organization: The student organization, intracurricular in SBAE, with its mission to “changes lives and prepares members for premier leadership, personal growth and career success through agricultural education.” (National FFA Organization, n.d.).

Limitations

While this study provided valuable insight into biotechnology within school-based agricultural education (SBAE) in Georgia, several limitations were present.

The generalizability of the study was limited to a selective sample of Georgia agricultural educators; however, the findings could have been transferable to other populations.

The instrument was carefully designed to capture characteristics, as well as internal and external factors, of teachers who incorporated biotechnology topics. However, there were potential unknown factors among the participants that may not have been accounted for in the instrument, thereby potentially affecting their responses. All efforts were made to mitigate any errors through design and testing. The validity of the instrument, that the instrument is testing what the researchers intended it to test, was achieved through several methods. The first was by using a known and tested instrument from similar work (Boone et al, 2006). Additionally, the instrument was reviewed and edited by the primary researcher, who has extensive knowledge and a background in teaching biotechnology in agricultural education courses in Georgia as well as a group of long-time survey researchers who specialize in instrument-based survey research methods in agricultural leadership, education, and communications. Reliability of the instrument, the likelihood that if conducted again, the results would be similar, can be a threat to instrument based research (Field, 2013). To test instrument reliability, Cronbach's Alpha was calculated for each construct being investigated. The results of the testing were well above the standard for internal consistency common in the field of Agricultural Leadership, Education, and Communications. The construct of importance ($N = 19$) was ($\alpha = 0.91$), knowledge ($N = 19$) was ($\alpha = 0.97$), and confidence ($N = 19$) was ($\alpha = 0.97$).

When using instrument-based survey methods, nonresponse bias or error has the potential to affect the results and could be considered a limitation if not properly addressed (Field, 2013). Lindner et al. (2001, 2002) outlined several common procedures for addressing nonresponse error, one of which was using *t-testing* to compare early and late respondents on variables of interest. A *t-test* was conducted to compare the responses of the respondents who responded to the first email (n = 15) with those of the group who received the final email (n = 17) regarding their perceived knowledge and competence. No differences were found between early and late respondents on their reported knowledge ($t(30) = 0.97$, $p = 0.34$) or their reported competence ($t(30) = 0.93$, $p = 0.36$). The results of these tests indicate that nonresponse bias is not a threat to the validity of these studies.

Chapter 2: Historical Analysis of Biotechnology Integration of Ag Ed in Georgia

Abstract

The purpose of this study was to analyze the history of biotechnology integration in Georgia Agricultural Education and to evaluate the accuracy, relevance, and necessity of current content standards within the Georgia Standards of Excellence (GSE). A qualitative historical research design was guided by Rogers' (2003) Diffusion of Innovations Theory and was used to examine archival documents, curriculum standards, policy publications, peer-reviewed journals, and communications with Georgia Agricultural Education staff. Findings indicated that Georgia fell within the early adopters category in implementing biotechnology into agricultural education, with integration occurring alongside national curriculum development in the late 1990s and early 2000s. Analysis of the Plant Science and Biotechnology and Animal Science Technology and Biotechnology courses revealed that over half of the biotechnology topics were addressed only at introductory levels, used outdated terminology and examples, and lacked current scientific depth. Major recommendations included revising the GSE to incorporate modern applications such as CRISPR, gene editing, and bioethics, and establishing a continuous curriculum review or resource update process aligned with national AFNR standards. These actions were recommended to ensure that Georgia Agricultural Education remained current with industry advancements and effectively prepared students for future agricultural and biotechnological careers.

Key Words

Biotechnology, History, Agricultural Education, Curriculum

Introduction

From the days of Gregor Mendel's work with pea genetics in the 1800s, biotechnology and its applications had been a part of agriculture. In the late 1900s, what became known as modern genetic engineering emerged, and DNA was discovered as the mechanism through which genetics were passed on. Biotechnology became a major agricultural force in the 1990s by introducing and commercially marketing genetically engineered crops for production. It should be noted that prior centuries had built the groundwork for this significant technological advancement, but it was this decade that brought about the "Gene Revolution," which forever transformed the agricultural industry (International Service for the Acquisition of Agri-biotech Applications, n.d.).

In 1917, the Smith-Hughes National Vocational Education Act formally established vocational agriculture courses with funding at the secondary level. Though agricultural education at the secondary level had been common since the beginning of public education (Bailey, 1904; Hummel & Hummel, 1913; Stewart & Getman, 1927; Stimson, 1942). This has often been recognized as the foundation of what became the modern formal high school agricultural education classes. The curriculum that was initially developed could not keep pace with the rapidly changing technologies that educators sought to incorporate into instruction during the latter part of the twentieth century. Biotechnology in agriculture grew significantly in the 1970s and 1980s, and, as a result, related terminology and concepts became popular in agricultural education (Boone et al., 2006). This period brought forth the realization that existing curricula were outdated and failed to keep up with the technological advancements necessary to sustain a growing world.

The phrase “feeding a world population of 9 billion by 2050” emerged in the late 2000s and early 2010s through the Food and Agriculture Organization of the United Nations (FAO, 2009). The 1990 National Council on Vocational Education took action and incorporated biotechnology into the curriculum (National Council on Vocational Education, 1990). As a result of these combined efforts, the 1998 Georgia Department of Education’s 2020 Vision for Agricultural Education identified biotechnology as a central theme. It also included goals to help educators achieve the vision, opportunities to build student awareness and appreciation of biotechnology, curriculum centered around biotechnology, and experiential learning opportunities in biotechnology (Georgia General Assembly, Senate Research Office, n.d.).

Georgia Agricultural Education curriculum was structured around pathways, as were all academic and CTAE programs in the state. These pathways consisted of three related and interconnected courses that built upon one another (Georgia Department of Education, n.d.). The agricultural education courses that comprised the Agriscience Systems Pathway included (1) Basic Agriculture Science, (2) Plant Science and Biotechnology, and (3) Animal Science Technology and Biotechnology. These courses contained the specific term biotechnology in their titles and integrated a greater number of science topics into the Georgia Standards of Excellence for each course (see Appendix D). Moreover, the accuracy, relevance, and necessity of these course standards were examined in this study. The researcher’s objective was to use this historical analysis to demonstrate that the standards were outdated, did not reflect modern agricultural biotechnology applications and examples, and therefore needed to be revised.

Theoretical Framework

The framework utilized in this study was Everett Rogers’ Diffusion of Innovations Theory (2003). The Diffusion of Innovations Theory was defined as a five-stage process, known as the Innovation-Decision Process, through which an innovation was adopted, including (1) knowledge [recognizing and understanding the innovation], (2) persuasion [forming a like or dislike toward the innovation], (3) decision [furthering the understanding of the innovation to accept or reject it], (4) implementation [putting the innovation into practice], and (5) confirmation [reinforcing the innovation decision or reversing it] (Rogers, 2003). Rogers' DOI Theory (2003) also identified five adopter categories that described how individuals adopted innovations. The categories included (1) innovators [2.5% of a population; gatekeepers of new innovations and risk-takers], (2) early adopters [13.5% of a population; those who reduced uncertainty for others by serving as role models], (3) early majority [34% of a population; those who adopted just ahead of the average group, acted cautiously, and required evidence of success], (4) late majority [34% of a population; those who adopted after the majority, usually because they were compelled to], and (5) laggards [16% of a population; those who were the last to adopt, if at all, due to being traditional and resistant to change].

This framework was applied in this study, as it provided the foundation to analyze how biotechnology was introduced and diffused as a content area within agricultural education in Georgia. Furthermore, this framework helped the study analyze the content standards in relation to biotechnology topics and evaluate their accuracy, necessity, and relevance to modern-day agriculture.

Purpose

The purpose of this study was to analyze the history of biotechnology integration in agricultural education in Georgia. This research was conducted as part of a larger study that examined the internal and external factors influencing Georgia agricultural educators in implementing biotechnology topics. The objectives that guided this study included:

1. What is the history of Biotechnology integration of Ag Ed in Georgia?
2. Are the current content standards accurate, relevant, and necessary in accordance with modern agriculture (present day)?

Methods

A qualitative historical research design was used to explain both the integration of biotechnology within Georgia's agricultural education curriculum and the alignment of current content standards with modern agriculture. Ary et al. (2014) described this research design as a means of gaining insight into past events. The study was directly aligned with the guidelines for historical research outlined by Fraenkel et al. (2019), which included (1) defining the problem, (2) locating relevant sources of historical information, (3) summarizing and evaluating the information found, and (4) interpreting and presenting the information as it related to the problem. Furthermore, Rogers' Diffusion of Innovation Theory (2003) provided a coding system for the information collected to interpret how biotechnology was integrated into agricultural education in Georgia. The DOI adopter categories were used to determine how Georgia was classified as an adopter of biotechnology within agricultural education.

Data Collection

For the first objective, which focused on the history of biotechnology integration into agricultural education in Georgia, sources were analyzed using historical content analysis. This process focused on policy shifts, curriculum changes, and educational standards to construct a timeline of biotechnology integration within Georgia's agricultural education system. Primary data sources included:

- Archived records and curriculum documents from the Georgia Department of Education

- State (Georgia) publications and policy statements
- Federal publications and policy statements
- Peer-reviewed journals that addressed biotechnology in agricultural education
- Personal communications from current and retired Georgia Agricultural Education state staff
- Additional resources from national and international agricultural organizations

For the second objective, the current course standards were examined for alignment with existing scientific and industry practices, their connection to real-world applications, and their value in preparing students for agricultural careers, using qualitative content analysis. For the two primary content courses (excluding the introductory course) in the Georgia Agriscience Systems Pathway, Plant Science and Biotechnology and Animal Science Technology and Biotechnology, the standards were compared against national benchmarks and curriculum outlines, industry practices and applications, and current and emerging needs identified by agricultural organizations such as the Food and Agriculture Organization (FAO) and the International Service for the Acquisition of Agri-biotech Applications (ISAAA). Nineteen topics were identified and adapted from the Boone et al., (2006) *Agriculture Science Teachers' Attitudes and Implementation of Biotechnology* instrument and were validated through an analysis of modern applications and practices derived from the aforementioned sources. These topics represented the most common terms associated with biotechnology in contemporary agricultural practice and application.

Data Analysis

The analysis was guided by the theoretical framework, Rogers' Diffusion of Innovations Theory (2003), to identify the stages of adoption of biotechnology curriculum in Georgia Ag Ed. The theory's five stages of the Innovation-Decision process were used to code milestones and trends into categories for accurate interpretation. To draw accurate conclusions, the findings were listed chronologically for Objective 1 and by theme for Objective 2. Research in adoption and diffusion is a hallmark of research in agricultural education (Lindner et al., 2016).

Findings

Objective 1: What is the history of Biotechnology integration of Ag Ed in Georgia?

Innovation-Decision Stage: Knowledge

Prior to the 1900s, formal agricultural education, as it was known in later years, did not exist. However, the Hatch Act of 1887 provided the foundation for the first agriscience programs in the United States by funding experimentation and scientific research (Hillison, 1996; Hatch Act, 1887). In the same historical analysis, Hillison (1996) discovered in a 1913 publication titled Agricultural Instruction that there was a connection between the experiment stations (created by the Hatch Act) and the development of secondary agriculture curricula, thereby giving rise to the first agriscience programs in the United States.

In 1917, the Smith-Hughes Vocational Education Act established federal funding for agricultural education at the secondary level. During this period, biotechnology was emerging in agriculture, gaining prominence as an innovative approach to advancing global agricultural practices. The Smith-Hughes Act ensured that this growing body of scientific knowledge was disseminated throughout secondary education (Boone et al., 2006).

In 1928, Hearst completed a study in an unpublished master's thesis and concluded that, for vocational education, (a) knowledge of the sciences was necessary, (b) basic principles and fundamentals should be taught, (c) science content should be taught by the vocational teacher, (d) science should be taught in connection with vocational subjects, and (e) certain instructional methods were agreed upon by the teachers (Hillison, 1996).

By 1981, the term biotechnology had still not been adopted in Georgia Agricultural Education or at the land-grant university level (F. Flanders, personal communication, September 18, 2025).

Innovation-Decision Stage: Persuasion

Nationally, in 1988, the Future Farmers of America changed its name to the National FFA Organization. This change was made to reflect the increasing diversity and growing importance of science, business, and technology within agriculture (National FFA Organization, 2025). As a direct result of the rise of biotechnology in agriculture during this period, this shift indicated that by the late 1980s, biotechnology had been recognized broadly enough within the agricultural field that a national organization found it necessary to adjust its identity.

During the late 1980s and into the 1990s, Dr. Frank Flanders and Dr. Ray Herren, professors at the University of Georgia, conducted teacher workshops on agriscience throughout the state. These workshops were developed to help agricultural education teachers gain the knowledge and skills needed to implement emerging agriscience and biotechnology topics into their curriculum.

Innovation-Decision Stage: Decision

By 1994, the National Occupational Skill Standards for Agricultural Education had formed a committee to develop standards that would better prepare students for the workforce. Agricultural biotechnology was included as part of the terminology within the national standards-writing process (F. Flanders, personal communication, September 18, 2025).

Two years later, in 1996, Dr. Frank Flanders became the Georgia State Agricultural Education Curriculum Coordinator under the State Director of Georgia Agricultural Education, Melvin B. Johnson. During this time, the Curriculum Renewal Project was initiated. Using the National Occupational Skill Standards for Agricultural Education as a foundation, detailed lesson plans were developed for every course in Georgia Agricultural Education and were distributed to teachers for implementation by the summer of 1997.

During the 1997–1998 school year, agriscience courses were presented before the Georgia State Board of Education for consideration as options that could qualify for science credit.

Innovation-Decision Stage: Implementation

In 1998, the Georgia Department of Education's 2020 Vision for Agricultural Education identified biotechnology as a central theme. Biotechnology was recognized as a key factor in how agriculture would advance to support a growing population, and it began to be acknowledged as an essential component to incorporate into agricultural education at the secondary level (Georgia General Assembly, Senate Research Office, n.d.).

Subsequently, a research study was conducted comparing the test scores of students enrolled in agriscience courses with those of students enrolled in traditional science courses, and the findings were presented to the Georgia State Board of Education in October 1999 (F. Flanders, personal communication, September 18, 2025). This study was intended to evaluate the effectiveness of implementing science-based instruction within agricultural education programs.

Innovation-Decision Stage: Confirmation

In October 1999, the Georgia State Board of Education approved agriscience courses for science credit as a direct result of the student test score study that had been presented earlier that month.

By 2003, the University of Georgia introduced a new Applied Biotechnology major for the Fall 2003 term within the College of Agricultural and Environmental Sciences. This postsecondary recognition of biotechnology's importance in agricultural education highlighted a growing disparity at the K–12 level, where similar emphasis on biotechnology was lacking (UGA CAES Newswire, field report; Holmes, 2003).

From 2003 to 2006, the USDA's National Institute of Food and Agriculture funded a grant at Fort Valley State University titled Educating the Educators: "The Future is Now" through Agbiotechnology Education Enrichment for K–12 School Teachers. This grant, the first of its kind in Georgia, provided extensive professional development for selected K–12 schools. It aimed to support teacher knowledge and readiness to implement biotechnology through facility development, curriculum design, and biotechnology training workshops. The overarching purpose was to establish and strengthen biotechnology programs for students, while also promoting USDA research and biotechnology initiatives (Fort Valley State University, 2006). This program preceded the Georgia Department of Education's formal recognition of biotechnology in its curriculum.

Also in 2006, a study conducted by Boone et al. revealed that agricultural education teachers in West Virginia were not adequately prepared to teach biotechnology-related topics, echoing similar concerns raised nationally.

In 2009, the Georgia State Board of Education approved a new course list that included biotechnology standards, a pathway framework, and recognition of these courses as satisfying the fourth science credit requirement for high school graduation. These changes were scheduled for implementation beginning in the 2011–2012 school year (Georgia Administrative Code, Rule 160-4-2-.03, 1990/2011). At that point, biotechnology was formally recognized in the titles of Georgia agricultural education courses, and the content was acknowledged as sufficiently rigorous to meet science graduation and college entrance requirements for the University System of Georgia.

During the 2013–2014 school year, the Georgia Department of Education officially adopted the National Career Clusters model for Agriculture, Food, and Natural Resources (AFNR) and released updated course standards (Georgia FFA Association, n.d.-a). This marked the foundational integration of biotechnology topics into Georgia's Plant Science and Biotechnology and Animal Science Technology and Biotechnology courses.

In 2020, the Rural Teacher Training Initiative (RTTI) was signed into law and received funding through the state budget. This initiative was designed to provide a select population of Georgia teachers with biotechnology-focused professional development, along with classroom materials, equipment, and curriculum support. It also facilitated partnerships between educators and industry professionals to create student career opportunities in biotechnology. As of the 2025–2026 school year, the initiative continued under the name Biotech Teacher Training Initiative, having expanded beyond rural areas to include all Georgia teachers (ERC Association, n.d.).

In 2023, the Georgia Department of Audits and Accounts conducted a Special Examination on educational standards, which outlined the history of standards development in Georgia, beginning with the Quality Basic Education (QBE) Act of 1985. The QBE Act established the Quality Core Curriculum (QCC), now known as the Georgia Standards of

Excellence (GSE). The act outlined a four-year revision cycle, although the report found that review, approval, and implementation often took four to six years. The Special Examination also found that some non-core content standards, such as those in Career, Technical, and Agricultural Education (CTAE), were written broadly to reduce the frequency of revisions. These standards allowed for incorporation of emerging content, such as biotechnology, based on input from industry professionals rather than a fixed timeline (Griffin & Kieffer, 2023).

Also in 2023, the National Council for Agricultural Education (NCAE) released updated AFNR Career Cluster Content Standards. These standards served as the foundational structure for school-based agricultural education (SBAE) nationwide and guided state and local course development. The skills and competencies outlined were developed through the combined efforts of industry leaders, educational standards committees, and national organizations such as the NCAE, National FFA Organization, and Advance CTE. Major revisions were noted to occur approximately every five to seven years (Advance CTE, 2020; The NCAE, 2023; Scott et al., 2025). With demand for SBAE teachers it is critical to assess and evaluate the programs (Williams, et al., 2025).

In 2025, the last official revision to Georgia's high school agricultural education standards for grades 9–12 was determined to have been the initial creation in 2013, which was adopted in 2014. In Spring 2025, the Plant Science and Biotechnology GSE underwent revision following the formation of a committee comprised of current agricultural education teachers, state staff, and industry professionals. However, the Animal Science Technology and Biotechnology GSE had not been revised, and, as of 2025, no committee had been formed to initiate the revision process (Dr. C. Steinkamp, B. Schwing, M. Riley, & J. Allen, personal communication, 2025).

Objective 2: Are the current content standards accurate, relevant, and necessary in accordance with modern agriculture (present day)?

The Georgia Standards of Excellence (GSE) for Plant Science and Biotechnology and Animal Science Technology and Biotechnology courses were cross-referenced with the 19 identified biotechnology topics to determine their level of inclusion within the standards, as well as their accuracy, necessity, and relevance to modern agricultural practice (Table 2.1).

Ten topics (52.63%) were included at an introductory level, recombinant DNA, gene splicing, genetic engineering, cloning, classification, resistant plant species, animal reproduction, growth hormones, biotechnology ethics, and diseases. Introductory-level topics were found to be foundational in nature; however, several required more in-depth coverage due to their high importance and relevance to the contemporary agricultural industry. These topics contained outdated terminology, examples, and protocols, along with an unclear instructional focus regarding their significance for inclusion.

Four topics (21.05%) were included at an intermediate level, transgenic species, genetically modified foods, and biotechnology lab techniques. Intermediate-level topics were found to be largely outdated in terms of regulations, practices, influences, and terminology used within the standards.

Two topics (10.53%) were included at an advanced level, plant tissue culture and plant reproduction. Advanced-level inclusion remained highly relevant to modern agricultural practices and applications but required updated terminology and the specification of current techniques.

Three topics (15.79%) were either not included or were only indirectly addressed, environmental biotechnology, food biotechnology, and microbial biotechnology. These topics lacked a clear instructional focus and demonstrated limited recognition of their importance within the broader context of biotechnology education.

Table 2.1

Biotechnology topics and their inclusion and relation to the GSE

Biotechnology Topic	Level of inclusion of topics in current standards in relation to topic	Updates needed to match modern practices/applications	Link to Standards
Recombinant DNA	Introductory	Only foundations covered, needs modern lab applications added in	ASB- 11 PSB- 6, 9, 10
Gene Splicing	Introductory	Outdated terminology and not using current tools (i.e. CRISPR-Cas)	ASB-11 PSB- 6, 9
Genetic Engineering	Introductory	Update examples (i.e. regulatory pathways, synthetic biology, etc.)	ASB- 8 PSB- 5, 6, 10
Cloning	Introductory	Concepts are outdated compared to current protocols	ASB- 8 PSB-5, 6, 9, 10, 13
Transgenic Species	Intermediate	Update with current regulations and public perception content	ASB- 8 PSB- 5, 6
Genetically Modified Food	Intermediate	Update with labeling, data-driven consumer debates and their influence	ASB- 8, 10 PSB- 5, 6
Biotechnology Laboratory Techniques	Intermediate	Update with modern, advanced lab techniques (i.e. technologies, PCR, CRISPR, etc.)	ASB- 1, 2, 3, 9 PSB- 1, 2, 3
Environmental Biotechnology	Not included/ indirect	Add in to standards to include topics such as bioremediation, GM trees, etc.	ASB- 8 PSB- 5, 9, 11, 19
Food Biotechnology	Not included/ indirect	Add in to standards to include topics such as enzymes, fermentation, GM traits, etc.	ASB- 8 PSB- 5
Microbial Biotechnology	Not included/ indirect	Add in to standards to include topics such as soil microbiomes, biofertilizers, fermentation, etc.	ASB- 18 PSB- 5

Hybridization	Intermediate	Update to include molecular hybridization	ASB- 11 PSB- 9, 10
Plant Tissue Culture	Advanced	None needed, still relevant	PSB- 5, 6
Resistant Plant Species	Introductory	Update to include modern resistance breeding	PSB- 5, 9
Animal Reproduction	Introductory	Update to include modern terminology (precision breeding, gene selection, embryo transfer, Artificial Insemination, etc.)	ASB- 13, 15, 17
Growth Hormones (bST, pST, GAs, CKs, etc.)	Introductory	Update to bring a clearer focus on the topic to include ethics, regulation, cases of using GH	ASB- 14, 16 PSB-5, 6
Biotechnology Ethics	Introductory	Update to bring a clearer focus on the topic as it is a major policy factor today (CRISPR offspring, food ethics, gene patenting, etc.)	ASB- 11, 12
Diseases	Introductory	Update to make it intermediate content in the sense of GM disease resistance, vaccines, RNA interference	ASB- 2, 8, 19, 20 PSB- 16
Plant Reproduction	Advanced	All included is still very relevant, but could be updated to include biotechnology advancements such as gene-edited seeds, etc.	PSB- 6, 8, 9, 13
Classification	Introductory	Update to include modern classification methods outside of taxonomy (i.e. genome data)	ASB- 7 PSB- 2, 4

Sources: Zaidi et al., 2020; Zhang & Liu, 2024; Khan et al., 2021; Harmon & Paul, 2020; Georgia FFA Association, n.d. b & c; Georgia Department of Education, n.d.; Georgia BioEd Institute, n.d.; Biotechnology Innovation Organization, 2020

Conclusions and Recommendations

Conclusions

It was concluded that Georgia Agricultural Education fell within the early adopters category according to Rogers' (2003) Diffusion of Innovation Theory. The Innovation-Decision process to implement biotechnology into agricultural education appeared to have occurred in conjunction with the creation of national standards and during the rise of biotechnology innovations within agricultural applications. Findings also indicated that in Georgia, educational standards were revised or updated more frequently outside of the normal four-year revision cycle only when a national education update occurred or when the state superintendent initiated a revision. Updating and implementing new standards was found to be both costly and time-consuming.

For non-core content areas such as Agricultural Education, it was discovered that these programs did not follow the typical four-year revision schedule because their standards were written broadly to prevent frequent revisions or updates. The four-year revision process itself posed challenges, as it could take up to six years before new standards were implemented, effectively restarting the revision cycle. Conversely, national leadership organizations such as the National Council for Agricultural Education, National FFA Organization, Advance CTE, industry professionals, and educational standards committees met regularly to review the national Agriculture, Food, and Natural Resources (AFNR) standards, with major revisions occurring approximately every five to seven years.

The two courses featured in this study, Plant Science and Biotechnology and Animal Science Technology and Biotechnology, were last revised during their initial creation in 2013–2014 (Table 2.2). If core content standards, including science, were among the most frequently updated in Georgia, agriculture-based sciences should have been considered for revision or updating as well, given that they were recognized as a fourth science credit option for graduation. Because these courses held a comparable level of rigor and importance to core science subjects, they should not have been left outdated or overlooked. Scott et al. (2025) demonstrated that, as science continued to be one of the most tested subject areas across states, agricultural curricula that included rigorous, standards-based laboratory experiences helped strengthen science literacy and improved student performance on assessments. It was also found that the plant-related course standards were currently undergoing revision; however, the process was in its early stages and was projected to take an additional four to six years before the updated standards would be implemented, pending approval.

Future research on this topic could have explored how Georgia agricultural education teachers developed or sourced their own instructional materials to integrate modern practices, techniques, applications, and examples related to biotechnology, given the broad wording of the standards. Further investigation could have examined whether clarifying standards with explicit examples and applications aligned to modern biotechnology would have encouraged teachers to implement biotechnology topics more meaningfully and effectively, thereby enhancing student learning and preparing future consumers of agricultural products.

Recommendations

Recommendation 1 It is recommended that action be taken to revise the standards, as they had not been updated since 2013–2014. During the revision process, it was advised that the broadly defined verbiage be refined to adopt a more narrowly focused approach that included modern terminology and applications, thereby helping teachers clearly identify the specific concepts and skills they needed to implement. Considering that the national Agriculture, Food, and Natural Resources (AFNR) standards are reviewed regularly and underwent major revisions every five to seven years, it is further recommended that state-level standards follow the same revision schedule.

Recommendation 2 Furthermore, it is recommended that if the standards revision process could not be modified, the broadly defined standards remain unchanged, but a study be conducted to examine the relevance, accuracy, and necessity of the curriculum resources provided alongside the standards on the Georgia Agricultural Education website. The successful integration of biotechnology depended not only on curriculum design but also on teachers' confidence, professional development, and access to high-quality instructional materials (Lambert et al., 2014; Ufnar & Shepherd, 2018; Scott et al., 2025). It was suggested that a task force or committee be established in collaboration with the Georgia Agricultural Education Curriculum Director to develop and maintain a cycle of frequently updated curriculum materials and resources for educators. Such an effort would ensure alignment with modern biotechnology applications and techniques, while also accelerating the process of equipping teachers with the tools needed to implement standards effectively.

These recommendations were intended to update the existing Georgia Standards of Excellence so that they align with the goals set forth by the National Council for Agricultural Education (2023) to provide rigorous, contemporary standards and resources across agricultural education pathways.

Table 2.2

Biotechnology topics and their inclusion and relation to the GSE

Biotechnology Topic	**Level of inclusion of topics in Current Standards in relation to Topic**	**Updates needed to match modern practices/applications**	**Link to Standards**
Recombinant DNA	Introductory	Only foundations covered, needs modern lab applications added in	ASB- 11 PSB- 6, 9, 10
Gene Splicing	Introductory	Outdated terminology and not using current tools (i.e. CRISPR-Cas)	ASB-11 PSB- 6, 9
Genetic Engineering	Introductory	Update examples (i.e. regulatory pathways, synthetic biology, etc.)	ASB- 8 PSB- 5, 6, 10
Cloning	Introductory	Concepts are outdated compared to current protocols	ASB- 8 PSB-5, 6, 9, 10, 13

Transgenic Species	Intermediate	Update with current regulations and public perception content	ASB- 8 PSB- 5, 6
Genetically Modified Food	Intermediate	Update with labeling, data-driven consumer debates and their influence	ASB- 8, 10 PSB- 5, 6
Biotechnology Laboratory Techniques	Intermediate	Update with modern, advanced lab techniques (i.e. technologies, PCR, CRISPR, etc.)	ASB- 1, 2, 3, 9 PSB- 1, 2, 3
Environmental Biotechnology	Not included/indirect	Add in to standards to include topics such as bioremediation, GM trees, etc.	ASB- 8 PSB- 5, 9, 11, 19
Food Biotechnology	Not included/indirect	Add in to standards to include topics such as enzymes, fermentation, GM traits, etc.	ASB- 8 PSB- 5
Microbial Biotechnology	Not included/indirect	Add in to standards to include topics such as soil microbiomes, biofertilizers, fermentation, etc.	ASB- 18 PSB- 5
Hybridization	Intermediate	Update to include molecular hybridization	ASB- 11 PSB- 9, 10
Plant Tissue Culture	Advanced	None needed, still relevant	PSB- 5, 6
Resistant Plant Species	Introductory	Update to include modern resistance breeding	PSB- 5, 9
Animal Reproduction	Introductory	Update to include modern terminology (precision breeding, gene selection, embryo transfer, Artificial Insemination, etc.)	ASB- 13, 15, 17
Growth Hormones (bST, pST, GAs, CKs, etc.)	Introductory	Update to bring a clearer focus on the topic to include ethics, regulation, cases of using GH	ASB- 14, 16 PSB-5, 6

Biotechnology Ethics	Introductory	Update to bring a clearer focus on the topic as it is a major policy factor today (CRISPR offspring, food ethics, gene patenting, etc.)	ASB- 11, 12
Diseases	Introductory	Update to make it intermediate content in the sense of GM disease resistance, vaccines, RNA interference	ASB- 2, 8, 19, 20 PSB- 16
Plant Reproduction	Advanced	All included is still very relevant, but could be updated to include biotechnology advancements such as gene-edited seeds, etc.	PSB- 6, 8, 9, 13
Classification	Introductory	Update to include modern classification methods outside of taxonomy (i.e. genome data)	ASB- 7 PSB- 2, 4

Sources: Zaidi et al., 2020; Zhang & Liu, 2024; Khan et al., 2021; Harmon & Paul, 2020; Georgia FFA Association, n.d. b & c; Georgia Department of Education, n.d.; Georgia BioEd Institute, n.d.; Biotechnology Innovation Organization, 2020

References

Advance CTE. (2020). *Without limits: A shared vision for the future of career technical education*. www.careertech.org/without-limits

Ary, D., Jacobs, L.C., Sorensen, C.K. and Walker, D. (2014) *Introduction to Research in Education*. 9th Edition, Wadsworth, Cengage Learning.

Bailey, L .H. (1904). What is Agricultural Education?, In L. H. Bailey (Eds.), *Cornell Nature Study Leaflets* (pp 45 – 54). J. B. Lyon Company Printers.

Biotechnology Innovation Organization. (2020). *The U.S. bioscience economy: Driving economic growth and opportunities in states and regions*. https://bio.widen.net/s/hflmb92hwx/the-us-bioscience-economy-driving-economic-growth-and-opportunities-in-states-and-regions?utm.com

Boone, H. N., Gartin, S. A., Boone, D. A., & Hughes, J. E. (2006). Modernizing the agricultural education curriculum: an analysis of agricultural education teachers' attitudes, knowledge, and understanding of biotechnology. *Journal of Agricultural Education*, *47*(1), 78–89. https://doi.org/10.5032/jae.2006.01078

ERC Association. (n.d.). *CMaT partnership with Georgia Bio establishes rural teacher training initiative to build a biomanufacturing workforce.* https://erc-assoc.org/achievement/cmat-partnershipgeorgia-bio-establishes-rural-teacher-training-initiative-build?utm.com

Food and Agriculture Organization of the United Nations. (2009). *Proceedings of the Expert Meeting on How to Feed the World in 2050.* Food and Agriculture Organization. https://www.fao.org/4/ak542e/ak542e00.htm?utm.com

Fort Valley State University. (2006). *Educating the Educators: "The Future Is Now" through AgBiotechnology Education Enrichment for K-12 school teachers* [Project summary].

National Institute of Food and Agriculture. https://portal.nifa.usda.gov/web/crisprojectpages/0198054-educating-the-educators-the-future-is-now-through-agbiotechnology-education-enrichment-for-k-12-school-teachers.html?utm.com

Fraenkel, J. R., Wallen, N. E., Hyun, H. H. (2019) *How to Design and Evaluate Research in Education* (10th ed.). McGraw-Hill Education.

Georgia Administrative Code, Rule 160-4-2-.03, List of State-Funded K-8 Subjects and 9-12 Courses for Students Entering Ninth Grade Prior to 2008. (1990 & rev. 2011). https://rules.sos.state.ga.us/gac/160-4-2-.03

Georgia BioEd Institute. (n.d.). *Biotech Teacher Training Initiative*. https://www.galifesciences.org/biotech-teacher-training-initiative

Georgia Department of Education. (n.d.). *Browse standards – CTAE: Agriculture, Food & Natural Resources*. https://case.georgiastandards.org/8d5c9983-ba6c-4dc4-849e-df2575c9745b/8d5c9983-ba6c-4dc4-849e-df2575c9745b

Georgia Department of Education. (n.d.). *Career Clusters/Pathways.* https://www.gadoe.org/Curriculum-Instruction-and-Assessment/CTAE/Pages/CTAE-Georgia-Career-Clusters.aspx

Georgia FFA Association. (n.d. a). *Georgia AFNR Standards*. https://georgiaffa.org/page.aspx?ID=125&utm.com

Georgia FFA Association. (n.d. b). *Animal science and biotechnology curriculum standards.* https://georgiaffa.org/curriculum/topic.aspx?TID=11

Georgia FFA Association. (n.d. c). *Plant science and biotechnology curriculum standards*. https://www.georgiaffa.org/curriculum/topic.aspx?TID=27&utm.com

Georgia General Assembly, Senate Research Office. (n.d.). *Agricultural education* [Study Committee Report No. 10]. https://www.senate.ga.gov/sro/Documents/StudyCommRpts/10AgEd.pdf

Griffin, G. S., & Kieffer, L. (2023). *23-13 SE education standards: Final draft (Special Examination Report No. 23-13)*. Georgia Department of Audits and Accounts, Performance Audit Division. https://www.audits.ga.gov/ReportSearch/download/30518

Harmon, R. L., & Paul, J. H. (2020). Current status of research, regulations, and future challenges for CRISPR gene editing in crop improvement. *UF/IFAS Extension*, *HS1315*. https://edis.ifas.ufl.edu/publication/HS1315?downloadOpen=true

Hatch Act, 7 U.S.C. § 361a *et seq*. (1887). https://uscode.house.gov/view.xhtml?req=(title:7%20section:361a%20edition:prelim)

Hillison, J. (1996). The origins of agriscience: or where did all that scientific agriculture come from?. *Journal of Agricultural Education*, *37*(4), 8–13. https://doi.org/10.5032/jae.1996.04008

Holmes, C. (2003). *UGA to offer applied biotechnology major* [Field Report]. University of Georgia College of Agricultural & Environmental Sciences. https://fieldreport.caes.uga.edu/news/uga-to-offer-applied-biotechnology-major/

Hummel, W. G., & Hummel, B. R. (1913). *Materials and Methods in High School Agriculture*. McMillan Company.

International Service for the Acquisition of Agri-biotech Applications. (n.d.). *Biotech in agriculture: Timeline.* https://www.isaaa.org/kc/inforesources/publications/biotechinagriculture/default.html#Biotech_Timeline_.htm?utm

Khan, A., Ali, A., Khan, H., & Amin, M. (2021). CRISPR/Cas: The new frontier in plant improvement. *ACS Agricultural Science & Technology*, *1*(5), 388–397. https://doi.org/10.1021/acsagscitech.1c00279

Lambert, M. D., Velez, J. J., & Elliott, K. M. (2014). What are the teachers' experiences when implementing the Curriculum for Agricultural Science Education? *Journal of Agricultural Education*, *55*(4), 100–115. https://doi.org/10.5032/jae.2014.04100

Lindner, J. R., Rodriguez, M. T., Strong, R., Jones, D., & Layfield, D. (2016). Research priority area 2: New technologies, practices, and products adoption decisions. American Association for Agricultural Education National Research Agenda, 2020, 19-27. https://aaea.wildapricot.org/resources/Documents/AAAE_National_Research_Agenda_2016-2020.pdf

National Council on Vocational Education (1990). *Occupational Competencies. A Study of the Vocational-Technical Education Needs of the Agribusiness and Chemistry-Based Technology Industries* [electronic resource]. Distributed by ERIC Clearinghouse. https://files.eric.ed.gov/fulltext/ED318861.pdf

National FFA Organization. (2025, January 13). *1988*. National FFA Organization. https://www.ffa.org/timeline/1988/

Rogers, E. M. (2003) *Diffusion of Innovations*. Free Press, New York.

Scott, J. D., Bird, T. D., Rubenstein, E. D., & Kvitko, B. H. (2025). Examining the Implementation of Plant Pathology Curricula in School-Based Agricultural Education: A Pilot Study. *Journal of Agricultural Education*, *66*(3), Article 25. https://doi.org/10.5032/jae.v66i3.3035

Stewart, R. M., & Getman, A. K. (1927). Teaching Agricultural Vocations. John Wiley & Sons, Inc.

Stimson, R. W. (1942). Historic Background Common to All States. In R. W. Stimson & F. W. Lathrop (Eds.), *History of Agricultural Education of Less than College Grade in the United States.* (pp1 – 8). Bulletin Prepared for the U. S. Office of Education, Federal Security Agency.

The National Council for Agricultural Education. (2023). *AFNR standards*. https://thecouncil.ffa.org/afnr/

Ufnar, J. A., & Shepherd, V. L. (2018). The scientist in the classroom partnership program: an innovative teacher professional development model. *Professional Development in Education*, *45*(1), 642–658. https://doi.org/10.1080/19415257.2018.1474487

Williams, J., McKibben, J. D., Clemons, C., Cletzer, D. A., Lindner, J. R. (2025). The Impacts of Balance, Engagement, and Commitment of Alabama SBAE Retention. Proceedings of the 2025 AAAE-Southern Region. https://doi.org/10.13140/RG.2.2.24688.57600

Zaidi, S. S.-e.-A., Vanderschuren, H., Qaim, M., Mahfouz, M. M., Kohli, A., Mansoor, S., & Tester, M. (2020). Engineering crops of the future: CRISPR approaches to develop climate-resilient and disease-resistant plants. *Genome Biology*, *21*(1), 289. https://doi.org/10.1186/s13059-020-02204-y

Zhang, X., & Liu, H. (2024). Genetic modification techniques in plant breeding: A comparative review of CRISPR/Cas and GM technologies. *Horticultural Plant Journal*, *10*(3), 212–225. https://doi.org/10.1016/j.hpj.2024.05.002

Chapter 3: Internal Factors for Success of Biotechnology Topics in Ag Ed

Abstract

The purpose of this study was to analyze the internal factors that influenced Georgia Agricultural Education teachers' implementation of biotechnology topics within the Plant Science and Biotechnology and Animal Science Technology and Biotechnology courses. Guided by Bandura's (1986) Social Cognitive Theory and Self-Efficacy Theory (1997), the study employed a quantitative survey design using an instrument adapted from Boone et al. (2006). The survey, distributed via Qualtrics to 64 Georgia agricultural educators during the 2024–2025 school year, measured teachers perceived importance, knowledge, and competence across 19 biotechnology topics. Data were analyzed using descriptive statistics and correlations. Findings revealed that while teachers viewed biotechnology topics as important ($M = 3.85$), they reported moderate knowledge ($M = 3.09$) and competence ($M = 3.29$) levels. A strong positive correlation was found between knowledge and competence ($r = .882$, $p < .001$). Major recommendations included providing targeted professional development in high-need areas, such as recombinant DNA, gene splicing, and transgenic species, and enhancing teacher preparation programs to improve confidence and instructional capacity. Strengthening biotechnology education through these measures was expected to ensure that Georgia's agricultural education remained rigorous, relevant, and aligned with modern scientific practices.

Key Words

Biotechnology, Agricultural Education, Animal Science, Plant Science, In-service needs

Introduction

Agricultural education in the United States continually evolved alongside advancements in science and technology following its formal establishment in the early twentieth century. The Smith-Hughes National Vocational Education Act of 1917 institutionalized vocational agriculture courses at the secondary level, forming the foundation for what was recognized as high school agricultural education. As agricultural technologies advanced rapidly during the latter half of the twentieth century, particularly with the emergence of biotechnology in the 1970s and 1980s, the inadequacies of existing curricula in keeping pace with these innovations became increasingly apparent (Boone et al., 2006). Although science had been a component of agricultural education since the passage of the Hatch Act of 1887 (Budke, 1991; Vaughn, 1993; Christian & Key, 1994; Hillison, 1996), it was not until the National Research Council's 1988 report that educators were explicitly charged with strengthening the scientific rigor of agricultural curricula (Thompson, 2001).

In Georgia, agricultural education was structured around career pathways, consistent with the framework applied across all Career, Technical, and Agricultural Education (CTAE) programs. Each pathway consisted of three sequential, interrelated courses that built upon one another to provide progressive skill development (Georgia Department of Education, n.d.). Within the Agriscience Systems Pathway, courses such as Basic Agriculture Science, Plant Science and Biotechnology, and Animal Science Technology and Biotechnology explicitly incorporated biotechnology concepts and scientific principles into the Georgia Standards of Excellence, reflecting the state's efforts to align agricultural education with contemporary advancements in the agricultural sciences.

Nationally, the Agriculture, Food, and Natural Resources (AFNR) Career Cluster Content Standards served as the foundational framework for School-Based Agricultural Education (SBAE) programs. These standards, developed through collaboration among educational organizations, industry representatives, and national leadership entities such as the National Council for Agricultural Education (NCAE), National FFA, and Advance CTE, were systematically revised every five to seven years to maintain alignment with industry expectations and workforce demands (Advance CTE, 2020; The NCAE, 2023; Scott et al., 2025).

Despite these ongoing curricular revisions, the effective integration of biotechnology within agricultural education ultimately depended on the knowledge, confidence, and instructional capacity of educators. Previous research identified persistent challenges associated with teaching biotechnology at the secondary level, including the complexity of the content, insufficient instructional time, limited access to laboratory resources, and gaps in teachers' understanding of scientific principles (Steele & Aubusson, 2004; Mowen et al, 2007; Pollard, 2020). However, empirical evidence suggested that targeted professional development, particularly through intensive, hands-on biotechnology workshops, significantly enhanced teacher confidence and instructional competence (Wilson et al., 2002) and that if teachers are shown a method more often that they are more likely to use it (Hancock et al., 2024). Therefore, the sustained success of biotechnology integration in agricultural education required continued investment in educator professional development, access to quality instructional materials, and systematic curriculum updates that reflected ongoing scientific and technological advancements (Lambert et al., 2014; Ufnar & Shepherd, 2018; Scott et al., 2025).

Theoretical Framework

Two frameworks were used in this study. The first was Albert Bandura's (1986) Social Cognitive Theory (SCT). The Social Cognitive Theory outlined four stages in the development of learning: (1) attention, (2) retention, (3) reproduction, and (4) motivation (Bandura, 1986). Bandura (1986) also identified a triadic reciprocal relationship within SCT among three factors: personal (one's cognitions, beliefs, emotional, and biological characteristics), behavioral (one's choices and actions), and environmental (social and external experiences). In summary, individuals learned not only through direct experiences but also through cognitive processes and by observing others. This framework was applied to examine how agricultural education teachers acquired knowledge of biotechnology and applied those topics within their classrooms.

The second framework utilized in this study was Bandura's (1997) Self-Efficacy Theory (SET). Bandura's Self-Efficacy Theory was developed as a direct extension of his 1986 Social Cognitive Theory. SET referred to an individual's belief in their own capability to succeed at a task through their actions. Specifically, it focused on four sources: (1) mastery experiences [engaging in tasks until success was achieved], (2) indirect experiences [observing others succeed at a task and developing the belief that one possessed similar ability], (3) social experiences [receiving positive feedback, encouragement, and affirmation from role models], and (4) internal experiences [interpreting one's inner dialogue to influence beliefs about personal capability] (Bandura, 1997). This framework was applied to understand agricultural education teachers' levels of confidence in their ability to teach biotechnology-related topics effectively.

Purpose

The purpose of this study was to analyze the internal factors that influenced Georgia Agricultural Educators in implementing biotechnology topics. This research was conducted as part of a larger study that examined the history of biotechnology integration in agricultural education and the external factors that affected Georgia Agricultural Educators' implementation of biotechnology topics. The objectives that guided this study were as follows:

1. What are teachers' perceived importance of, personal knowledge, and competency of teaching biotechnology topics?
2. What in-service needs can be determined by the teachers' perceived importance of personal knowledge, and competency of teaching biotechnology topics?

Methods

This study implemented a quantitative survey instrument that was adapted from the Boone et al., (2006) *Agriculture Science Teachers' Attitudes and Implementation of Biotechnology* study. It served as the foundation, with adjustments made to the topics, order of questions, and overall formatting. A group of teacher education specialists at West Virginia University had previously reviewed the instrument to confirm both content validity and face validity (Mowen et al., 2007). The survey was designed in Qualtrics and distributed via email to participants. An initial email, along with three follow-up reminders, was sent to participants over a two-month period, beginning in July 2025 and concluding in September 2025 (Dillman et al., 2014). To encourage participation, participants were informed that they had been invited specifically to take part in the study rather than through a general listserv email to the broader population (McKibben et al., 2025). Overall, the methods for this study were guided by Dillman et al.'s (2014) tailored design method, as the emails were personalized to establish a sense of connection, promote social exchange, and reduce nonresponse. Additionally, McKibben et al.'s (2025) call to emphasize the need for rebuilding community trust by using targeted sampling methods rather than relying on mass emails or listservs was taken into account when designing the data collection.

Participants

The population for this study consisted of Georgia Agricultural Education teachers during the 2024–2025 school year who taught Plant Science and Biotechnology and/or Animal Science Technology and Biotechnology courses (N = 173). The list of teachers was obtained by the researcher from the state's program manager, who provided the information via email in a private spreadsheet. The list included each teacher's name, school name, and the course(s) taught. Teachers' email addresses were then obtained from the Georgia Agricultural Education website's public directory.

During the 2024–2025 school year, 173 course sections were offered in Georgia Agricultural Education classrooms, 145 sections of Animal Science Technology and Biotechnology and 28 sections of Plant Science and Biotechnology. Additionally, 145 schools offered at least one of the two courses; 25 schools offered both courses, and 3 schools offered only Plant Science and Biotechnology. Seventeen teachers (N = 173) taught both courses, leaving a total of 156 unique individuals to be sampled.

Yamane's formula was used to determine the sample for survey instrument distribution (Yamane, 1967). Based on the formula: $\frac{N}{1+N(e^2)}$, where (e^2) is the level of precision expected, in this case (0.05), the sample needed for coverage was 64 individuals. Therefore, 64 invitations were sent to potential participants, and 32 individuals (n = 32) completed the instrument with usable responses, resulting in a 50% response rate (Table 3.1).

Table 3.1

Participant Characteristics (n=32).

Characteristics	*f*	%
Age		

22	1	3.1
23	1	3.1
25	2	6.3
26	1	3.1
27	3	9.4
29	4	12.5
30	2	6.3
31	3	9.4
32	3	9.4
33	1	3.1
39	1	3.1
40	2	6.3
43	1	3.1
45	1	3.1
46	1	3.1
47	1	3.1
50	1	3.1
54	1	3.1
58	1	3.1
62	1	3.1
Gender		
Male	9	28.1
Female	23	71.9
Path to Certification		
Undergraduate Student Teaching	22	68.8
Graduate Student Teaching	3	9.4
Industry Credential/Certification	3	9.4
Other	4	12.5
Ethnicity		
Black or African American	3	9.4
White	28	87.5

Not Listed	1	3.1
Highest Level of Education		
Bachelors	8	25.0
Masters	11	34.4
Specialist	10	31.3
Doctorate	3	9.4
Years Teaching		
1-5	9	28.1
6-10	12	37.5
11-15	4	12.5
16-20	3	9.4
21-25	3	9.4
26-30	1	3.1
Years Teaching Agriculture		
1-5	9	28.1
6-10	13	40.6
11-15	2	6.3
16-20	4	12.5
21-25	3	9.4
26-30	1	3.1
Area of Specialty		
Agricultural Mechanics	1	3.1
Animal Science	19	59.4
Biotechnology	1	3.1
FFA	4	12.5
Forestry	1	3.1
Horticulture	4	12.5
Other	2	6.3
Certification Area		
Agricultural Education	24	75.0
Agricultural Education and Additional Areas	8	25.0

Science Certification		
No Science Certification	27	84.4
Science Certification	5	15.6

Instrumentation and Data Analysis

The survey instrument was designed using the Borich Model (1980) to measure the competencies of teachers who taught biotechnology topics (Caillouet & Harder, 2022). This is a common procedure to evaluate agricultural education concepts (Faulk et al, 2024; Ray et al, 2022). This portion of the instrument was structured into three major sections: importance, knowledge, and competency. The list of 19 biotechnology topics served as the competencies measured as internal factors influencing teacher success. These items were paired with a five-point summated scale in which 1 = not important, no knowledge, or not competent; 2 = somewhat not important, some knowledge, or mostly not competent; 3 = neither/nor important, am knowledgeable, or neither/nor competent; 4 = somewhat important, fairly knowledgeable, or mostly competent; and 5 = very important, extensive knowledge, or competent.

Lindner et al. (2001, 2002) outlined procedures for addressing nonresponse error through comparisons of early and late respondents, while Lindner and Lindner (2024) provided the framework for interpreting summated-scale scores (Figure 3.1). A *t-test* was conducted to compare the responses of the respondents who responded to the first email ($n = 15$) with those of the group who received the final email ($n = 17$) regarding their perceived knowledge and competence. No differences were found between early and late respondents on their reported knowledge ($t(30) = 0.97$, $p = 0.34$) or their reported competence ($t(30) = 0.93$, $p = 0.36$). The results of these tests indicate that nonresponse bias is not a threat to the validity of these studies. The data were collected through Qualtrics and analyzed using IBM SPSS statistical software.

Figure 3.1

Intervals and Interpretation of a Five-Point Summated Scale

Intervals and Interpretations of a Five-Point Summated Scale

Interval One	Interval Two	Interval Three	Interval Four

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
5	4	3	2	1

SA	A	NAE	D	SD
5-4.51	4.50 - 3.51	3.50 - 2.51	2.50 - 1.51	1.50 - 1

Note. An *n* point summated scale will have *n*-1 equal intervals

Note. Adapted from "Interpreting Likert-type Scales, Summated Scales, Unidimensional Scales, and Attitudinal Scales: I neither Agree nor Disagree, Likert or Not" article (Lindner & Lindner, 2024).

Findings

Objective 1: What are teachers' perceived importance of, personal knowledge, and competency of teaching biotechnology topics?

Participants neither agreed nor disagreed on the overall importance of biotechnology topics for a student in their courses to learn by the end of the course (M= 3.85, SD= 0.58). Participants also neither agreed or disagreed on their overall level of knowledge (M= 3.09, SD= 0.91) or competence (M= 3.29, SD= 0.95) to teach biotechnology topics in their courses (Table 3.2).

Table 3.2

Descriptive Statistics of Participants' Overall Knowledge, Competence, and Importance of Teaching Biotechnology Topics in Agriculture.

	M	*SD*
Knowledge	3.09	.905
Competence	3.29	.945
Importance	3.85	.577

Note. Knowledge, Competence, and Importance is ranked on a 5-point summated scale. 1 = not important, no knowledge, or not competent, and 5 = very important, lot of knowledge, or competent

A statistically significant correlation existed between participants' Knowledge and Competence ($r = .882$, $p < .001$). A statistically significant correlation did not exist between Knowledge and Importance ($r = .203$, $p = .264$) nor between Competence and Importance ($r = .215$, $p = .237$) (Table 3.3).

Table 3.3

Correlations of Participants Knowledge, Competence, and Importance

	Knowledge		Competence		Importance	
	r	*p-value*	*r*	*p-value*	*r*	*p-value*
Knowledge	--	--	.882**	<.001	.203	.264
Competence	--	--	--	--	.215	.237

*Note. ** Correlation is significant at the 0.01 level (2-tailed).*

Objective 2: What in-service needs can be determined by the teachers' perceived importance of personal knowledge, and competency of teaching biotechnology topics?

Participants strongly agreed that two of the nineteen topics were important for their students to know by the end of the course (M = 4.51–5.00). Moreover, participants agreed on the importance of seven topics for their students to know by the end of the course (M = 3.51–4.50). Lastly, for ten topics, participants neither agreed nor disagreed regarding their importance for students to know by the end of the course (M = 2.51–3.50) (see Table 3.4).

Table 3.4

Means and standard deviations for Importance of Biotechnology Topics for Students

Biotechnology Topic	*M*	*SD*
Animal Reproduction	4.81	0.39
Diseases	4.56	0.50
Genetically Modified Food	4.47	0.76
Plant Reproduction	4.41	0.95
Classification	4.34	0.83
Food Biotechnology	4.06	0.80
Growth Hormones (bST, pST, GAs, CKs, etc.)	4.06	0.72
Environmental Biotechnology	4.03	0.78
Biotechnology Ethics	4.03	0.82
Cloning	3.88	0.94
Genetic Engineering	3.84	1.14
Biotechnology Laboratory Techniques	3.84	1.05
Resistant Plant Species	3.78	1.04
Hybridization	3.72	1.02
Plant Tissue Culture	3.34	1.07
Microbial Biotechnology	3.28	1.05
Transgenic Species	3.03	1.18
Gene Splicing	2.84	1.22
Recombinant DNA	2.81	1.20

Note. Level of Importance is ranked on a 5-point summated scale. 1 = not important, and 5 = very important

Participants strongly agreed that one of the nineteen topics was an area in which they were most knowledgeable (M = 4.51–5.00). Three topics were identified where participants agreed they were knowledgeable (M = 3.51–4.50). Participants neither agreed nor disagreed regarding their level of knowledge for twelve topics (M = 2.51–3.50). Lastly, participants disagreed on their level of knowledge for three topics (M = 1.51–2.50) (see Table 3.5).

Table 3.5

Descriptive Statistics for Participants Knowledge of Biotechnology Topics

Topic	*M*	*SD*
Animal Reproduction	4.22	0.91
Diseases	3.81	1.03
Plant Reproduction	3.78	1.10
Classification	3.75	1.21
Genetically Modified Food	3.50	0.95
Growth Hormones (bST, pST, GAs, CKs, etc.)	3.41	1.07
Biotechnology Ethics	3.19	1.26
Biotechnology Laboratory Techniques	3.16	1.17
Food Biotechnology	3.09	1.17
Cloning	3.06	1.11
Resistant Plant Species	2.97	1.06
Environmental Biotechnology	2.94	1.16
Hybridization	2.81	1.18
Genetic Engineering	2.72	1.17
Plant Tissue Culture	2.69	1.28
Transgenic Species	2.56	1.34
Microbial Biotechnology	2.44	1.19
Gene Splicing	2.41	1.07
Recombinant DNA	2.22	1.10

Note. Level of Knowledge is ranked on a 5-point summated scale. 1 = no knowledge, and 5 = lot of knowledge

Participants agreed that they were competent to teach five of the nineteen biotechnology topics (M = 3.51–4.50). For eleven biotechnology topics, participants neither agreed nor disagreed regarding their competence to teach them (M = 2.51–3.50). Lastly, participants disagreed on their competence to teach three of the biotechnology topics (M = 1.51–2.50) (see Table 3.6).

Table 3.6

Descriptive Statistics for Participants Competence of Biotechnology Topics

Topic	*M*	*SD*
Animal Reproduction	4.34	1.01
Plant Reproduction	4.16	0.99
Classification	4.09	1.09
Diseases	3.94	1.08
Genetically Modified Food	3.66	1.15
Biotechnology Ethics	3.50	1.16
Food Biotechnology	3.47	0.98
Growth Hormones (bST, pST, GAs, CKs, etc.)	3.47	1.27
Resistant Plant Species	3.44	1.29
Biotechnology Laboratory Techniques	3.31	1.20
Cloning	3.28	1.28
Environmental Biotechnology	3.22	1.24
Hybridization	3.13	1.19
Plant Tissue Culture	3.00	1.14
Microbial Biotechnology	2.78	1.13
Genetic Engineering	2.75	1.41
Transgenic Species	2.47	1.32
Gene Splicing	2.34	1.41
Recombinant DNA	2.31	1.40

Note. Level of Competence is ranked on a 5-point summated scale. 1 = not competent, and 5 = competent

Conclusions, Discussion, and Recommendations

This study found that teachers agreed that biotechnology topics were important for their students to learn by the end of the Plant Science and Biotechnology and Animal Science and Biotechnology courses; however, they did not demonstrate a strong sense of knowledge or competence to teach those topics. A similar study conducted by Newman and Johnson (1994) revealed that, in Mississippi, teachers perceived the importance of biotechnology in their agriscience courses to be very high, yet they reported the lowest levels of competence in this area. Therefore, it is recommended that in Georgia, in-service professional development for 13 (68%) of the biotechnology topics was greatly needed to raise the mean responses toward the "agree" level (M = 3.51–4.50) for both knowledge and competence, thereby enhancing teachers' ability to teach effectively. Topics such as Recombinant DNA, Gene Splicing, Transgenic Species, Microbial Biotechnology, and Genetic Engineering should be prioritized for training. The Plant Science and Biotechnology and Animal Science and Biotechnology courses need to include sufficiently rigorous content to continue qualifying as a fourth science credit option for Georgia high school graduation. Agricultural educators are expected to provide robust, standards-aligned instruction that connect agriculture to interdisciplinary topics such as science (Scott et al., 2025). Teachers who were more knowledgeable and competent in these areas were better able to fulfill that expectation.

This study also suggested that teacher preparation programs should consider the enrichment of biotechnology content within their curriculum. Teacher education programs have the potential to influence teachers' development of pedagogical and technical skills necessary to increase the scientific content embedded within agricultural education (Thompson & Warnick, 2007). Although teachers generally possess substantial agricultural content knowledge, their comfort with integrating advanced scientific concepts vary. Prior research demonstrated that confidence in teaching advanced science topics was closely tied to teacher preparation and access to relevant professional development (DiBenedetto, 2015; Lambert et al., 2014; Scott et al., 2025).

Future research could focus on the external factors, such as resources, students, and community influences, that impact the success of biotechnology integration into agricultural education. As the push for interdisciplinary teaching continues to evolve, the success of scientific integration within agricultural education depends not only on teachers' confidence but also on curriculum design, professional development opportunities, and access to high-quality instructional materials (Lambert et al., 2014; Ufnar & Shepherd, 2018; Scott et al., 2025). Another recommendation for future research is to investigate specific professional development needs related to biotechnology topics within the existing course standards of the two biotechnology-focused courses, to better prepare educators to maximize student learning opportunities. Replicating this study in other states to gain a broader perspective on biotechnology integration within agricultural education could lead to new directions in curriculum reform, professional development, or teacher preparation programs that enhance educators' skills and confidence in biotechnology instruction.

References

Advance CTE. (2020). *Without limits: A shared vision for the future of career technical education.* www.careertech.org/without-limits

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Prentice-Hall.

Bandura, A. (1997). *Self-efficacy: The exercise of control.* W. H. Freeman.

Boone, H. N., Gartin, S. A., Boone, D. A., & Hughes, J. E. (2006). Modernizing the agricultural education curriculum: an analysis of agricultural education teachers' attitudes, knowledge, and understanding of biotechnology. *Journal of Agricultural Education, 47*(1), 78–89. https://doi.org/10.5032/jae.2006.01078

Borich, G. D. (1980). A needs assessment model for conducting follow-up studies. *Journal of Teacher Education, 31*(3), 39–42. https://doi.org/10.1177/002248718003100310

Budke, W. E. (1991). Agriculture science- Striving for excellence. T*he Agricultural Education Magazine, 63*(7), 4, 11. https://www.naae.org/naae/document-server/?cfp=/naae/assets/file/public/magazine/volume63/v63i7.pdf

Caillouet, O., & Harder, A. (2022). *Conducting the needs assessment #8: The Borich model* (Publication WC415). University of Florida IFAS Extension. https://edis.ifas.ufl.edu/publication/WC415

Christian, T., & Key, J. P. (1994). *Agriscience equal to science*. (Eric Document Reproduction Service No. ED 334421) https://files.eric.ed.gov/fulltext/ED334421.pdf

DiBenedetto, C. A. (2015). *Teachers' perceptions of their proficiency and responsibility to teach the knowledge, skill, and dispositions required of high school students to be career ready* *in the 21st century* [Doctoral dissertation, University of Florida]. University of Florida Institutional Repository. https://files.eric.ed.gov/fulltext/EJ1249819.pdf

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). *Internet, phone, mail, and mixed mode surveys: The tailored design method* (4th ed.). John Wiley & Sons, Inc.

Faulk, B., McKibben, J. D., Clemons, C. A. & Lindner, J. R. (2024). Instructor Levels of Importance and Competence With Alabama Agricultural Mechanics Standards. *Journal of Southern Agricultural Education Research, 74*(1). http://jsaer.org/wpcontent/uploads/2024/12/74-Faulk-McKibben-Clemons-Lindner.pdf

Georgia Department of Education. (n.d.). *Career Clusters/Pathways.* https://www.gadoe.org/Curriculum-Instruction-and-Assessment/CTAE/Pages/CTAE-Georgia-Career-Clusters.aspx

Hancock, G. T., Hancock, C. E., & McKibben, J. D. (2024). The Teaching Techniques of Alabama's Traditionally and Alternatively Certified School-Based Agricultural Education Instructors. *Journal of Agricultural Education, 65*(3), 18–34. https://doi.org/10.5032/jae.v65i3.166

Hillison, J. (1996). The origins of agriscience: or where did all that scientific agriculture come from. *Journal of Agricultural Education, 37*(4), 8–13. https://doi.org/10.5032/jae.1996.04008

Lambert, M. D., Velez, J. J., & Elliott, K. M. (2014). What are the teachers' experiences when implementing the Curriculum for Agricultural Science Education? *Journal of Agricultural Education*, *55*(4), 100–115. https://doi.org/10.5032/jae.2014.04100

Lindner, J. R., & Lindner, N. (2024). Interpreting Likert type, summated, unidimensional, and attitudinal scales: I neither agree nor disagree, Likert or not. *Advancements in Agricultural Development*, *5*(2), 152–163. https://doi.org/10.37433/aad.v5i2.351

Lindner, J. R., Murphy, T. H., & Briers, G. E. (2001). Handling Nonresponse In Social Research. *Journal of Agricultural Education*, *42*(4), 43–53. https://doi.org/10.5032/jae.2001.04043

Lindner, J. R. (2002). Handling of non-response in the Journal of International Agricultural and Extension Education. *Journal of International Agricultural and Extension Education*, *9*(3), 55-60. https://doi.10.5191/jiaee.2002.09307

McKibben, J. D., Clemons, C. A., & Blythe, J. M. (2025). Survey response rates by requestor's characteristics. *Advancements in Agricultural Development, 6*(1), 43–54. https://doi.org/10.37433/aad.v6i1.525

Mowen, D. L., Roberts, T. G., Wingenbach, G. J., & Harlin, J. F. (2007). Biotechnology: An Assessment Of Agricultural Science Teachers' Knowledge and Attitudes. *Journal of Agricultural Education*, *48*(1), 42–51. https://doi.org/10.5032/jae.2007.01042

Newman, M. E., & Johnson, D. M. (1994). Inservice Education Needs of Teachers of Pilot Agriscience Courses in Mississippi. J*ournal of Agricultural Education*, *35*(1), 54–60. https://doi.org/10.5032/jae.1994.01054

Pollard, M. (2020) *A historical analysis of the 2020 agricultural education vision plan and the reformation of agricultural education in Georgia as it intended*. (Publication No. 181) [Doctoral dissertation, Murray State University]. Murray State's Digital Commons. https://digitalcommons.murraystate.edu/etd/181

Ray, B. L., Clemons, C. A., McKibben, J. D., Lindner, J. R., Fuhrman, N. E., & Barlow, R. J. (2022). Implementing Forestry and Natural Resource Curricula in Georgia. A Quantitative Analysis of Perceived Barriers Towards Implementation. *Journal of Agricultural Education, 63*(3), 149–165. https://doi.org/10.5032/jae.2022.03149

Scott, J. D., Bird, T. D., Rubenstein, E. D., & Kvitko, B. H. (2025). Examining the Implementation of Plant Pathology Curricula in School-Based Agricultural Education: A Pilot Study. *Journal of Agricultural Education*, *66*(3), Article 25. https://doi.org/10.5032/jae.v66i3.3035

Steele, F., & Aubusson, P. (2004). The challenge in teaching biotechnology. *Research in Science Education*, *34*, 365-387. https://doi.org/10.1007/s11165-004-0842-1

The National Council for Agricultural Education. (2023). *AFNR standards*. https://thecouncil.ffa.org/afnr/

Thompson, G. W. (2001). Perceptions Of Oregon Secondary Principals Regarding Integrating Science Into Agricultural Science And Technology Programs. *Journal of Agricultural Education*, *42*(1), 50–60. https://doi.org/10.5032/jae.2001.01050

Thompson, G. W., & Warnick, B. K. (2007). Integrating Science Into The Agricultural Education Curriculum: Do Science And Agriculture Teachers Agree?. *Journal of Agricultural Education*, *48*(3), 1–12. https://doi.org/10.5032/jae.2007.03001

Ufnar, J. A., & Shepherd, V. L. (2018). The scientist in the classroom partnership program: an innovative teacher professional development model. *Professional Development in Education*, *45*(1), 642–658. https://doi.org/10.1080/19415257.2018.1474487

Vaughn, P. R. (1993). Teaching agriscience: A few cautions. *The Agricultural Education Magazine*, *66* (4), 4. https://www.naae.org/naae/document-server/?cfp=/naae/assets/file/public/magazine/volume66/v66i7.pdf

Wilson, E., Kirby, B., & Flowers, J. (2002). Factors Influencing The Intent Of North Carolina Agricultural Educators To Adopt Agricultural Biotechnology Curriculum. *Journal of Agricultural Education*, *43*(1), 69–81. https://doi.org/10.5032/jae.2002.01069

Yamane, T. (1967), *Statistics: An Introductory Analysis* (2nd Edition). Harper & Row. https://archive.org/details/statisticsanintr0000taro/page/n7/mode/2up

Chapter 4: External Factors for Success of Biotechnology Topics in Ag Ed

Abstract

This study examined the external factors that influenced Georgia agricultural educators' ability to implement biotechnology topics within the Agriscience Systems Pathway. Guided by Bandura's (1986) Social Cognitive Theory and Self-Efficacy Theory (1997), the research analyzed teachers' resources, student characteristics, and community support related to biotechnology instruction. A quantitative survey was adapted from Boone et al. (2006) and distributed to 64 agricultural educators who taught Plant Science and Biotechnology and/or Animal Science Technology and Biotechnology, yielding 32 usable responses (50% response rate). Results indicated that teachers had sufficient internet access, technology, and administrative support but lacked instructional materials, laboratory equipment, and adequate time to teach biotechnology concepts. Respondents strongly agreed that students preferred hands-on learning but identified limited home support and uneven science readiness as barriers. Communities were found to support agricultural education broadly but demonstrated minimal awareness of biotechnology. The study concluded that these external factors impeded effective biotechnology integration and recommended ongoing professional development, curriculum resource updates, and stronger interdisciplinary collaboration to enhance instructional capacity. Future research was recommended to explore teacher preparation, community perceptions, and replication of this study across other states to strengthen national efforts toward modernized agricultural education.

Key Words

Biotechnology, Agricultural Education, Animal Science, Plant Science, Barriers

Introduction

Agricultural education in the United States continually evolved alongside advancements in science and technology following its formal establishment in the early twentieth century. The Smith-Hughes National Vocational Education Act of 1917 institutionalized vocational agriculture courses at the secondary level, forming the foundation for what was recognized as high school agricultural education. As agricultural technologies advanced rapidly during the latter half of the twentieth century, particularly with the emergence of biotechnology in the 1970s and 1980s, the inadequacies of existing curricula in keeping pace with these innovations became increasingly apparent (Boone et al., 2006). Although science had been a component of agricultural education since the passage of the Hatch Act of 1887 (Budke, 1991; Vaughn, 1993; Christian & Key, 1994; Hillison, 1996), it was not until the National Research Council’s 1988 report that educators were explicitly charged with strengthening the scientific rigor of agricultural curricula (Thompson, 2001).

Agricultural education in its most modern form is best described as being represented by a three circle model (Croom, 2008). Those circles are class based instruction, FFA, and Supervised Agricultural Experiences (SAE). Georgia's administrative circles are class-based instruction, FFA, and Supervised Agricultural Experiences the students they serve should have a balanced and representative experience that contains equal parts of these three areas. SAE have been shown to have positive economic impacts in the community in which they are carried out (Hanagriff, et al., 2010).

Georgia agricultural education focuses are structured around career pathways, consistent with the framework applied across all Career, Technical, and Agricultural Education (CTAE) programs. Each pathway consisted of three sequential, interrelated courses that built upon one another to provide progressive skill development (Georgia Department of Education, n.d.). Within the Agriscience Systems Pathway, courses such as Basic Agriculture Science, Plant Science and Biotechnology, and Animal Science Technology and Biotechnology explicitly incorporated biotechnology concepts and scientific principles into the Georgia Standards of Excellence, reflecting the state's efforts to align agricultural education with contemporary advancements in the agricultural sciences.

Nationally, the Agriculture, Food, and Natural Resources (AFNR) Career Cluster Content Standards served as the foundational framework for School-Based Agricultural Education (SBAE) programs. These standards, developed through collaboration among educational organizations, industry representatives, and national leadership entities such as the National Council for Agricultural Education (NCAE), National FFA, and Advance CTE, were systematically revised every five to seven years to maintain alignment with industry expectations and workforce demands (Advance CTE, 2020; The NCAE, 2023; Scott et al., 2025).

Despite these ongoing curricular revisions, the effective integration of biotechnology within agricultural education ultimately depended on the knowledge, confidence, and instructional capacity of educators. Previous research identified persistent challenges associated with teaching biotechnology at the secondary level, including the complexity of the content, insufficient instructional time, limited access to laboratory resources, and gaps in teachers' understanding of scientific principles (Steele & Aubusson, 2004; Mowen et al., 2007; Pollard, 2020). However, empirical evidence suggested that targeted professional development, particularly through intensive, hands-on biotechnology workshops, significantly enhanced teacher confidence and instructional competence (Wilson et al., 2002). Therefore, the sustained success of biotechnology integration in agricultural education required continued investment in educator professional development, access to quality instructional materials, and systematic curriculum updates that reflected ongoing scientific and technological advancements (Lambert et al., 2014; Ufnar & Shepherd, 2018; Scott et al., 2025).

Theoretical Framework

Two frameworks were used in this study. The first was Albert Bandura's (1986) Social Cognitive Theory (SCT). The Social Cognitive Theory outlined four stages in the development of learning: (1) attention, (2) retention, (3) reproduction, and (4) motivation (Bandura, 1986). Bandura (1986) also identified a triadic reciprocal relationship within SCT among three factors: personal (one's cognitions, beliefs, emotional, and biological characteristics), behavioral (one's choices and actions), and environmental (social and external experiences). In summary, individuals learned not only through direct experiences but also through cognitive processes and by observing others. This framework was applied to examine how agricultural education teachers acquired knowledge and what barriers existed to the adoption of biotechnology and applied those topics within their classrooms. Research has shown that adoption of innovations cannot be achieved until barriers are overcome (Chang, et al., 2015; Harder, et al., 2008; & Li, et al., 2007)

The second framework utilized in this study was Bandura's (1997) Self-Efficacy Theory (SET). Bandura's Self-Efficacy Theory was developed as a direct extension of his 1986 Social Cognitive Theory. SET referred to an individual's belief in their own capability to succeed at a task through their actions. Specifically, it focused on four sources: (1) mastery experiences [engaging in experiences until success was achieved], (2) indirect experiences [observing others succeed at a task and developing the belief that one possessed similar ability], (3) social experiences [receiving positive feedback, encouragement, and affirmation from role models], and (4) internal experiences [interpreting one's inner dialogue to influence beliefs about personal capability] (Bandura, 1997). This framework was applied to understand agricultural education teachers' levels of confidence in their ability to teach biotechnology-related topics effectively.

Purpose

The purpose of this study was to analyze the external factors that influenced Georgia Agricultural Educators in implementing biotechnology topics. This research was conducted as part of a larger study that examined the history of biotechnology integration in agricultural education and the internal factors that affected Georgia Agricultural Educators' implementation of biotechnology topics. The objectives that guided this study were as follows:

1. What are teachers' barriers to teaching and information sources of biotechnology topics?
2. What resources are needed to lessen the external factors for success of teaching biotechnology in ag ed, based on the above?

Methods

This study implemented a quantitative survey instrument that was adapted from the Boone et al. (2006) *Agriculture Science Teachers' Attitudes and Implementation of Biotechnology* study. It served as the foundation, with adjustments made to the topics, order of questions, and overall formatting. A group of teacher education specialists at West Virginia University had previously reviewed the instrument to confirm both content validity and face validity (Mowen et al., 2007). The survey was designed in Qualtrics and distributed via email to participants. An initial email, along with three follow-up reminders, was sent to participants over a two-month period, beginning in July 2025 and concluding in September 2025 (Dillman et al., 2014). To encourage participation, participants were informed that they had been specifically invited to take part in the study, rather than through a general listserv email sent to the broader population (McKibben et al., 2025). Overall, the methods for this study were guided by Dillman et al.'s (2014) tailored design method, as the emails were personalized to establish a sense of connection, promote social exchange, and reduce nonresponse. Additionally, McKibben et al's (2025) call to emphasize the need for rebuilding community trust by using targeted sampling methods rather than relying on mass emails or listservs was taken into account when designing the data collection.

Participants

The population for this study consisted of Georgia Agricultural Education teachers during the 2024–2025 school year who taught Plant Science and Biotechnology and/or Animal Science Technology and Biotechnology courses (N = 173). The list of teachers was obtained by the researcher from the state's program manager, who provided the information via email in a private spreadsheet. The list included each teacher's name, school name, and the course(s) taught. Teachers' email addresses were then obtained from the Georgia Agricultural Education website's public directory.

During the 2024–2025 school year, 173 course sections were offered in Georgia Agricultural Education classrooms, 145 sections of Animal Science Technology and Biotechnology and 28 sections of Plant Science and Biotechnology. Additionally, 145 schools offered at least one of the two courses; 25 schools offered both courses, and 3 schools offered only Plant Science and Biotechnology. Seventeen teachers (N = 173) taught both courses, leaving a total of 156 unique individuals to be sampled.

Yamane's formula was used to determine the sample for survey instrument distribution (Yamane, 1967). Based on the formula: $\frac{N}{1+N(e^2)}$ where (e^2) is the level of precision expected, in this case (0.05), the sample needed for coverage was 64 individuals. Therefore, 64 invitations were sent to potential participants, and 32 individuals (n = 32) completed the instrument with usable responses, resulting in a 50% response rate (see Table 4.1).

Table 4.1

Participant Characteristics (n=32).

Characteristics	*f*	%
Age		
22	1	3.1
23	1	3.1
25	2	6.3
26	1	3.1
27	3	9.4
29	4	12.5
30	2	6.3
31	3	9.4
32	3	9.4
33	1	3.1
39	1	3.1
40	2	6.3
43	1	3.1
45	1	3.1
46	1	3.1
47	1	3.1
50	1	3.1
54	1	3.1
58	1	3.1
62	1	3.1
Gender		
Male	9	28.1
Female	23	71.9

Path to Certification		
Undergraduate Student Teaching	22	68.8
Graduate Student Teaching	3	9.4
Industry Credential/Certification	3	9.4
Other	4	12.5
Ethnicity		
Black or African American	3	9.4
White	28	87.5
Not Listed	1	3.1
Highest Level of Education		
Bachelors	8	25.0
Masters	11	34.4
Specialist	10	31.3
Doctorate	3	9.4
Years Teaching		
1-5	9	28.1
6-10	12	37.5
11-15	4	12.5
16-20	3	9.4
21-25	3	9.4
26-30	1	3.1
Years Teaching Agriculture		
1-5	9	28.1
6-10	13	40.6
11-15	2	6.3
16-20	4	12.5
21-25	3	9.4
26-30	1	3.1
Area of Specialty		
Agricultural Mechanics	1	3.1
Animal Science	19	59.4

Biotechnology	1	3.1
FFA	4	12.5
Forestry	1	3.1
Horticulture	4	12.5
Other	2	6.3
Certification Area		
Agricultural Education	24	75.0
Agricultural Education and Additional Areas	8	25.0
Science Certification		
No Science Certification	27	84.4
Science Certification	5	15.6

Instrumentation and Data Analysis

The survey instrument was designed using the Borich Model (1980) to measure the competencies of teachers who taught biotechnology topics (Caillouet & Harder, 2022). This is a common procedure to evaluate agricultural education concepts (Faulk et al., 2024; Ray et al., 2022). Three major sections structured this portion of the instrument: teacher resources provided and used, students, and community.

The resource-based questions were paired with a five-point summated scale in which 1 = I did not have any, 2 = I had some but not enough, 3 = I could have used a little more but it was not hindering, 4 = I had enough, and 5 = I had more than enough. The questions regarding students and community were presented on a five-point summated scale of agreement where 1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, and 5 = Strongly Agree.

Lindner et al. (2001, 2002) outlined procedures for addressing nonresponse error through a comparison of early and late respondents, while Lindner and Lindner (2024) provided the basis for interpreting summated-scale scores (Figure 4.1). A *t-test* was conducted to compare the responses of the respondents who responded to the first email (*n* = 15) with those of the group who received the final email (*n* = 17) regarding their perceived knowledge and competence. No differences were found between early and late respondents on their reported knowledge ($t(30) = 0.97$, $p = 0.34$) or their reported competence ($t(30) = 0.93$, $p = 0.36$). The results of these tests indicate that nonresponse bias is not a threat to the validity of these studies. The data were collected through Qualtrics and analyzed using IBM SPSS statistical software.

Figure 4.1

Intervals and Interpretation of a Five-Point Summated Scale

Intervals and Interpretations of a Five-Point Summated Scale

Interval One	Interval Two	Interval Three	Interval Four

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
5	4	3	2	1

SA	A	NAE	D	SD
5-4.51	4.50 - 3.51	3.50 - 2.51	2.50 - 1.51	1.50 - 1

Note. An *n* point summated scale will have *n*-1 equal intervals

Note. Adapted from "Interpreting Likert-type Scales, Summated Scales, Unidimensional Scales, and Attitudinal Scales: I neither Agree nor Disagree, Likert or Not" article (Lindner & Lindner, 2024)

Findings

This research was guided by two objectives: What are teachers' barriers to teaching and information sources of biotechnology topics, and what resources are needed to lessen the external factors for success of teaching biotechnology in ag ed, based on the above?

Respondents collectively agreed (M = 3.51–4.50) that they had enough resources in three categories for teaching biotechnology topics: internet/connectivity, information technology, and administrative support. However, for the remaining eight types of teaching resources (e.g., classroom/laboratory space, time to teach, instructional materials, etc.), respondents neither agreed nor disagreed (M = 2.51–3.50) that they had sufficient resources for teaching biotechnology topics (see Table 4.2).

Table 4.2

Descriptive Statistics of Teaching Resources

Resource Type	*M*	*SD*
Internet/Connectivity	4.17	0.89
Information Technology (computers, tablets, etc.)	4.07	1.09
Administration Support	3.52	0.99
Classroom/Lab space	3.45	1.02
Time to teach	3.38	0.94
Personal (teacher) Knowledge	3.24	0.83
Textbooks/Physical Curriculum	2.97	1.02
Time to plan	2.89	0.94
Student Academic Ability	2.83	0.93
Scientific/Lab Equipment	2.79	1.26
Instructional Materials	2.76	1.02

Respondents indicated that they never used (mode = 6) lesson or curriculum resources from workshops (PLUs/education-based or industry-led), university courses, or artificial intelligence for biotechnology topic information. Each semester (mode=4), respondents collectively reported that premade lesson plans were their primary source of biotechnology topic information for lessons or curriculum. One source, social media teacher groups, was selected equally as both used monthly (mode = 3) and never used (mode = 6) as a source of information by respondents. Lastly, other agriculture teachers were selected as a source used monthly (mode =3) for biotechnology information for lessons and curriculum (see Table 4.3).

Table 4.3

Descriptive Statistics of Use of Lesson/Curriculum Resources for Biotechnology Information

Resource	*Mode*	*SD*
Workshops (PLUs/education based)	6	1.13
Workshops (Industry-led)	6	0.92
University Courses	6	1.57
Pre-made lesson plans	4	1.52
Social Media Teacher Groups	3*	1.65
Other Ag Teachers	3	1.43
Artificial Intelligence	6	1.87

*Note. *Multiple modes exist, least value is shown. 1= used daily, and 6= never used*

Respondents strongly agreed (M = 4.51–5.00) that a primary student characteristic was a preference for the hands-on learning aspect of agriculture compared to traditional methods of learning. Respondents agreed (M = 3.51–4.50) that their students had active Supervised Agricultural Experiences (SAEs) and understood the basics of the scientific method. It was noted that for twelve of the sixteen identified student characteristics, respondents neither agreed nor disagreed. Collectively, respondents disagreed (M = 1.51–2.50) that their students had the home support they needed to learn effectively (see Table 4.4).

Table 4.4

Descriptive Statistics of Teacher's Interpretations of their Student Characteristics

My students...	*M*	*SD*
… prefer the hands-on learning aspect of agriculture compared to traditional methods of learning.	4.60	0.72

… have active SAEs.	3.83	0.79
… understand the basics of the scientific method.	3.73	0.83
… have good access to the internet at home.	3.33	1.42
… have enough time at home to study.	3.20	1.47
… can read well enough to do well in my class.	3.20	1.16
… understand science well enough to do well in my class.	3.20	1.22
… have a passion for agriculture.	3.13	1.04
… have the study skills they need to be successful in my class.	3.13	1.17
… have SAEs that relate to the class they are taking currently.	3.13	1.01
… understand math well enough to do well in my class.	3.00	1.23
… want to learn the science of agriculture.	2.90	1.03
… have critical thinking skills to figure out solutions to problems.	2.87	0.94
… have a strong desire to learn.	2.73	1.14
… prioritize school.	2.53	1.07
… have the support at home they need to learn.	2.47	1.20

When describing the characteristics of their communities, respondents agreed (*M* = 3.51–4.50) with four statements. This included agreement that the community supported the agricultural education program, agriculture in general, teaching efforts, and individual student Supervised Agricultural Experience (SAE) projects. The remaining nine statements were neither agreed nor disagreed upon (*M* = 2.51–3.50) (see Table 4.5).

Table 4.5

Descriptive Statistics of Teacher's Interpretations of their Community Characteristics

My community...	*M*	*SD*
… supports the ag program.	3.90	1.02
… supports agriculture	3.83	0.98
… supports teaching.	3.80	0.96
… supports individual students SAE projects.	3.53	1.17

… is academically progressive.	3.33	1.09
… understands that agricultural education enriches the learning of core subjects.	3.33	1.21
… engages in adult and community education and other programs hosted by the ag program.	3.33	1.09
… sees a future in agriculture for the community.	3.27	1.26
… sees a future in agriculture for the students.	3.27	1.26
… has an accurate view of agriculture.	3.20	1.24
… wants me to teach biotechnology.	2.83	1.05
… has an accurate view of biotechnology.	2.67	1.03
… is quick to adopt new things.	2.60	1.13

Conclusions, Discussion, and Recommendations

The findings of this study indicated that Georgia agricultural education teachers faced multiple challenges in implementing biotechnology instruction. Although adequate administrative support, technology, and internet access were available, factors such as limited instructional materials, insufficient instructional time, and constrained classroom or laboratory space presented notable external barriers to implementation. Teachers primarily relied on premade lesson plans and peer support from other agriculture teachers for biotechnology instruction, while resources from workshops, university courses, and artificial intelligence were largely unused. This suggests a need for more accessible, classroom-ready biotechnology materials and professional development formats that effectively support teacher confidence and instructional integration.

Agricultural education was recognized for its emphasis on experiential, hands-on learning experiences. The study revealed that students overwhelmingly preferred this hands-on approach compared to traditional instructional methods. Additionally, Supervised Agricultural Experiences

(SAEs) and students' foundational understanding of the scientific method both served to mitigate some of the barriers associated with teaching biotechnology. However, the remaining twelve student characteristics examined varied considerably in levels of agreement among respondents. This suggested a significant need for stronger interdisciplinary collaboration and cross-curricular integration. Moreover, the findings indicated that many students lacked the necessary home support to reinforce biotechnology learning outside the classroom.

Community engagement was identified as a cornerstone of successful agricultural education programs, shaping curriculum decisions that aligned with workforce development needs. While this study found that Georgia communities continued to demonstrate traditional support for agricultural education, agriculture itself, and student SAE projects, respondents expressed neutral perspectives regarding most biotechnology-related statements. This neutrality raised concerns about the general community's awareness and understanding of biotechnology in agricultural education.

Future research should further investigate the student-related barriers identified in this study, particularly those with neutral response patterns, such as proficiency in science and mathematics or critical thinking skills. Additionally, research examining community perceptions could identify targeted strategies to help agricultural educators strengthen public understanding and support for biotechnology. Replicating this study across other states would provide a broader perspective on the resources and barriers encountered by teachers integrating biotechnology into agricultural education. Furthermore, analyzing relationships between teacher characteristics and survey responses could yield insights into specific factors influencing successful implementation, thereby narrowing the focus to the most significant barriers to biotechnology integration.

References

Advance CTE. (2020). *Without limits: A shared vision for the future of career technical education*. www.careertech.org/without-limits

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Prentice-Hall.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. W. H. Freeman.

Boone, H. N., Gartin, S. A., Boone, D. A., & Hughes, J. E. (2006). Modernizing the agricultural education curriculum: an analysis of agricultural education teachers' attitudes, knowledge, and understanding of biotechnology. *Journal of Agricultural Education*, *47*(1), 78–89. https://doi.org/10.5032/jae.2006.01078

Borich, G. D. (1980). A needs assessment model for conducting follow-up studies. *Journal of Teacher Education, 31*(3), 39–42. https://doi.org/10.1177/002248718003100310

Budke, W. E. (1991). Agriculture science- Striving for excellence. T*he Agricultural Education Magazine, 63*(7), 4, 11. https://www.naae.org/naae/document-server/?cfp=/naae/assets/file/public/magazine/volume63/v63i7.pdf

Caillouet, O., & Harder, A. (2022). *Conducting the needs assessment #8: The Borich model* (Publication WC415). University of Florida IFAS Extension. https://edis.ifas.ufl.edu/publication/WC415

Chang, C., & Lindner, J. R. (2017). Taiwanese Smallholder Farmers' Perceptions and Barriers to Adopting Facebook. *Journal of International Agricultural and Extension Education, 24*(3), 36-51. DOI: https://doi.org/10.5191/jiaee.2017.24304

Croom, D. B. (2008). The development of the integrated three-component model of agricultural education. *Journal of Agricultural Education, 49*(1), 110–120. https://doi.org/10.5032/jae.2008.01110

Christian, T., & Key, J. P. (1994). *Agriscience equal to science*. (Eric Document Reproduction Service No. ED 334421) https://files.eric.ed.gov/fulltext/ED334421.pdf

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). *Internet, phone, mail, and mixed mode surveys: The tailored design method* (4th ed.). John Wiley & Sons, Inc.

Faulk, B. McKibben, J. D., Clemons, C. A., & Lindner, J. R. (2024). Instructor Levels of Importance and Competence with Alabama Agricultural Mechanics Standards. Journal of Southern Agricultural Education Research, 74(1). http://jsaer.org/wpcontent/uploads/2024/12/74-Faulk-McKibben-Clemons-Lindner.pdf

Georgia Department of Education. (n.d.). *Career Clusters/Pathways*. https://www.gadoe.org/Curriculum-Instruction-and-Assessment/CTAE/Pages/CTAE-Georgia-Career-Clusters.aspx

Hanagriff, R. D., Murphy, T. H., Roberts, T. G., Briers, G. E., & Lindner, J. R. (2010). Economic Impact of Supervised Agricultural Experiences: Returns from SAE Investment Costs in Texas, 2007–2008. *Journal of Agricultural Education*, *51*(4), 71–81. https://doi.org/10.5032/jae.2010.04071

Harder, A., & Lindner, J. R. (2008). Going global with Extension: Barriers to the adoption of a web-based resource. *Journal of International Agricultural and Extension Education*, *15*(3), 69-80.

Hillison, J. (1996). The origins of agriscience: or where did all that scientific agriculture come from?. *Journal of Agricultural Education*, *37*(4), 8–13. https://doi.org/10.5032/jae.1996.04008

Lambert, M. D., Velez, J. J., & Elliott, K. M. (2014). What are the teachers' experiences when implementing the Curriculum for Agricultural Science Education? *Journal of Agricultural Education*, *55*(4), 100–115. https://doi.org/10.5032/jae.2014.04100

Li, Y., & Lindner, J. R. (2007). Barriers to diffusion of web-based distance education at China Agricultural University. *Journal of International Agricultural and Extension Education*, *14*(1), 45-57.

Lindner, J. R., & Lindner, N. (2024). Interpreting Likert type, summated, unidimensional, and attitudinal scales: I neither agree nor disagree, Likert or not. *Advancements in Agricultural Development*, *5*(2), 152–163. https://doi.org/10.37433/aad.v5i2.351

Lindner, J. R., Murphy, T. H., & Briers, G. E. (2001). Handling Nonresponse in Social Research. *Journal of Agricultural Education*, *42*(4), 43–53. https://doi.org/10.5032/jae.2001.04043

Lindner, J. R. (2002). Handling of non-response in the Journal of Internationl Agricultural and Extension Education. *Journal of Internationl Agricultural and Extension Education*, *9*(3), 55-60. https://doi.10.5191/jiaee.2002.09307

McKibben, J. D., Clemons, C. A., & Blythe, J. M. (2025). Survey response rates by requestor's characteristics. *Advancements in Agricultural Development, 6*(1), 43–54. https://doi.org/10.37433/aad.v6i1.525

Mowen, D. L., Roberts, T. G., Wingenbach, G. J., & Harlin, J. F. (2007). Biotechnology: An Assessment Of Agricultural Science Teachers' Knowledge And Attitudes. *Journal of Agricultural Education*, *48*(1), 42–51. https://doi.org/10.5032/jae.2007.01042

Pollard, M. (2020) *A historical analysis of the 2020 agricultural education vision plan and the reformation of agricultural education in Georgia as it intended*. (Publication No. 181) [Doctoral dissertation, Murray State University]. Murray State's Digital Commons. https://digitalcommons.murraystate.edu/etd/181

Ray, B. L., Clemons, C. A., McKibben, J. D., Lindner, J. R., Fuhrman, N. E., & Barlow, R. J. (2022). Implementing Forestry and Natural Resource Curricula in Georgia. A Quantitative Analysis of Perceived Barriers Towards Implementation. *Journal of Agricultural Education, 63*(3), 149–165. https://doi.org/10.5032/jae.2022.03149

Scott, J. D., Bird, T. D., Rubenstein, E. D., & Kvitko, B. H. (2025). Examining the Implementation of Plant Pathology Curricula in School-Based Agricultural Education: A Pilot Study. *Journal of Agricultural Education*, *66*(3), Article 25. https://doi.org/10.5032/jae.v66i3.3035

Steele, F., & Aubusson, P. (2004). The challenge in teaching biotechnology. *Research in Science Education*, *34*, 365-387. https://doi.org/10.1007/s11165-004-0842-1

The National Council for Agricultural Education. (2023). *AFNR standards.* https://thecouncil.ffa.org/afnr/

Thompson, G. W. (2001). Perceptions of Oregon Secondary principals regarding Integrating science into agricultural science and technology programs. *Journal of Agricultural Education*, *42*(1), 50–60. https://doi.org/10.5032/jae.2001.01050

Ufnar, J. A., & Shepherd, V. L. (2018). The scientist in the classroom partnership program: an innovative teacher professional development model. *Professional Development in Education*, *45*(1), 642–658. https://doi.org10.1080/19415257.2018.1474487

Vaughn, P. R. (1993). Teaching agriscience: A few cautions. *The Agricultural Education Magazine*, *66* (4), 4. https://www.naae.org/naae/document-server/?cfp=/naae/assets/file/public/magazine/volume66/v66i7.pdf

Wilson, E., Kirby, B., & Flowers, J. (2002). Factors influencing the intent of north carolina agricultural educators to adopt agricultural biotechnology curriculum. *Journal of Agricultural Education*, *43*(1), 69–81. https://doi.org/10.5032/jae.2002.01069

Yamane, T. (1967), *Statistics: An Introductory Analysis* (2nd Edition). Harper & Row. https://archive.org/details/statisticsanintr0000taro/page/n7/mode/2up

Chapter 5: Conclusions and Discussion

This dissertation examined the integration of biotechnology in school-based agricultural education in Georgia.

Summary of Findings by Study

Article 1:

Objective 1: History of Biotechnology Integration in Georgia Agricultural Education

Innovation-Decision Stage: Knowledge.

The foundation of agriscience education began with the Hatch Act of 1887, which funded agricultural research and established early connections between experiment stations and secondary agriculture curricula (Hillison, 1996; Hatch Act, 1887). The Smith-Hughes Act of 1917 further advanced scientific agricultural instruction through federal support (Boone et al., 2006), and early leaders emphasized integrating scientific principles into vocational training (Hillison, 1996). However, biotechnology had not yet been introduced into Georgia agricultural education by 1981 (F. Flanders, personal communication, September 18, 2025).

Innovation-Decision Stage: Persuasion.

During the Persuasion stage, agriculture education began shifting toward a science- and technology-focused identity, demonstrated by the National FFA Organization's 1988 name change (National FFA Organization, 2025). In support of this transition, agriscience workshops led by Drs. Frank Flanders and Ray Herren during the late 1980s and 1990s encouraged Georgia agriculture teachers to adopt biotechnology instruction through targeted professional development.

Innovation-Decision Stage: Decision.

During the Decision stage, formal steps were taken to adopt biotechnology within agricultural education. The 1994 National Occupational Skill Standards incorporated Agricultural Biotechnology, signaling national endorsement of its instructional value (F. Flanders, personal communication, September 18, 2025). In response, Dr. Flanders (1996) initiated Georgia's Curriculum Renewal Project, aligning state curriculum with these standards and introducing agriscience courses positioned for potential science credit approval.

Innovation-Decision Stage: Implementation.

During the Implementation stage, biotechnology became actively integrated into Georgia agricultural education. The Georgia Department of Education's 1998 *"2020 Vision"* identified biotechnology as a critical theme for advancing agricultural instruction (Georgia General Assembly, Senate Research Office, n.d.). Supporting this direction, a 1999 study demonstrated that agriscience students performed comparably to traditional science students, reinforcing the academic credibility of agriscience coursework (F. Flanders, personal communication, September 18, 2025).

Innovation-Decision Stage: Confirmation.

During the Confirmation stage, biotechnology integration in Georgia agricultural education became firmly established and continually strengthened. Agriscience courses received approval for science credit in 1999, solidifying biotechnology's academic legitimacy at the secondary level, followed by the University of Georgia's 2003 development of an Applied Biotechnology major, demonstrating postsecondary demand (Holmes, 2003).

Institutional support expanded through Fort Valley State University's USDA-NIFA grant (2003–2006), which funded teacher training and biotechnology facilities (Fort Valley State

University, 2006). National and state findings continued to reinforce the need for teacher preparation, as Boone et al. (2006) reported widespread educator unpreparedness.

Major policy milestones included biotechnology being added as a fourth science credit course in 2009 (Georgia Administrative Code, Rule 160-4-2-.03, 1990/2011) and its integration into AFNR Career Cluster standards in 2013–2014. Continued commitment to professional development emerged through the Rural Teacher Training Initiative in 2020, renamed the Biotech Teacher Training Initiative in 2025 (ERC Association, n.d.).

Ongoing standards review, including the 2023 DOAA confirmation of flexible CTAE revision cycles (Griffin & Kieffer, 2023) and national AFNR standards updates (Advance CTE, 2020; The NCAE, 2023; Scott et al., 2025), reflects sustained validation of biotechnology education. Most recently, Georgia revised the Plant Science and Biotechnology GSE in 2025, with Animal Science revisions have not yet begun (Dr. C. Steinkamp, B. Schwing, M. Riley, & J. Allen, personal communication, 2025).

Objective 2: Accuracy, Relevance, and Necessity of Current Content Standards

Analysis of the Georgia Standards of Excellence (GSE) for Plant and Animal Science Biotechnology revealed uneven coverage of essential biotechnology concepts when cross-referenced with 19 identified topics (see Table 2.1). Over half of the topics (52.63%) were included only at an introductory level, such as recombinant DNA, gene splicing, cloning, and biotechnology ethics, though much of the content was outdated. An additional 21.05% were represented at an intermediate level, including transgenic species, GM foods, and laboratory techniques, but required updated terminology and instructional practices. Advanced topics accounted for only 10.53% of alignment, as seen in plant tissue culture and reproduction, which remain relevant but need modernization. The remaining 15.79%—including environmental, food, and microbial biotechnology—were either absent or only indirectly referenced, demonstrating notable curriculum gaps and signaling a need for comprehensive revision.

Article 2:

Objective 1: Teachers' Importance of, Personal Knowledge, and Competence in Teaching Biotechnology Topics

Findings indicated that teachers held neutral perceptions regarding the importance of biotechnology topics for students (M = 3.85, SD = 0.58), as well as their own knowledge (M = 3.09, SD = 0.91) and competence (M = 3.29, SD = 0.95) to teach them. A strong positive correlation emerged between teachers' perceived knowledge and competence ($r = .882$, $p < .001$), suggesting that increased knowledge is closely associated with greater instructional confidence. However, no significant relationship was found between perceived importance and either knowledge ($r = .203$, $p > .001$) or competence ($r = .215$, $p > .001$), indicating that valuing biotechnology as important does not necessarily translate to teacher preparedness or instructional ability.

Objective 2: In-Service Needs Based on Teachers' Knowledge, Competence, and Importance Ratings

Teachers' Importance of Biotechnology Topics

Teachers expressed the highest perceived importance for Animal Reproduction (M = 4.81) and Diseases (M = 4.56), with additional agreement on seven biotechnology topics, including Genetically Modified Food (M = 4.47), Plant Reproduction (M = 4.41), Classification (M = 4.34), Food Biotechnology (M = 4.06), and Growth Hormones, Environmental Biotechnology, and Biotechnology Ethics (M = 4.03 each). Ten topics—including Cloning, Genetic Engineering, Resistant Plant Species, and Hybridization—received neutral importance ratings, indicating uncertainty or limited familiarity. The lowest levels of perceived importance were reported for Recombinant DNA (M = 2.81) and Gene Splicing (M = 2.84), suggesting areas where teacher professional development is most needed.

Teachers' Knowledge of Biotechnology Topics

Teachers reported the highest perceived knowledge in Animal Reproduction (M = 4.22), with moderate knowledge in topics such as Diseases (M = 3.81), Plant Reproduction (M = 3.78), and Classification (M = 3.75). Most biotechnology topics received neutral knowledge ratings, indicating limited confidence across a wide range of content areas. The lowest knowledge levels were reported in Gene Splicing (M = 2.41), Recombinant DNA (M = 2.22), and Microbial Biotechnology (M = 2.44), suggesting critical deficiencies in foundational molecular biotechnology concepts.

Teachers' Competence in Teaching Biotechnology Topics

Teachers reported the highest levels of instructional competence in Animal Reproduction (M = 4.34), Plant Reproduction (M = 4.16), Classification (M = 4.09), Diseases (M = 3.94), and Genetically Modified Food (M = 3.66). Competence ratings across eleven topics were neutral, including Biotechnology Ethics (M = 3.50) and Food Biotechnology (M = 3.47), indicating uncertainty or inconsistent instructional practice. The lowest competence ratings were found in advanced molecular biotechnology topics such as Transgenic Species (M = 2.47), Gene Splicing (M = 2.34), and Recombinant DNA (M = 2.31), identifying major areas where targeted professional development is needed.

Overall Knowledge, Competence, & Importance

Overall, teachers acknowledged the general importance of biotechnology but reported limited confidence in their knowledge and competence to teach related content. Their strongest proficiency remained within traditional agricultural science areas such as animal and plant reproduction, while advanced molecular biotechnology topics—such as recombinant DNA, gene splicing, and transgenic species—represented the greatest instructional weaknesses and professional development needs. The strong positive relationship between perceived knowledge and competence suggests that increased training and exposure would likely enhance teachers' ability to effectively deliver biotechnology instruction.

Article 3:

Objective 1: What are teachers' barriers to teaching and information sources of biotechnology topics?

Objective 2: What resources are needed to lessen the external factors for success of teaching biotechnology in ag ed, based on the above?

Teaching Resources

Teachers reported having adequate access to foundational infrastructure resources such as internet connectivity (M = 4.17), information technology (M = 4.07), and administrative support (M = 3.52), suggesting that basic systems were in place to support biotechnology instruction. However, they expressed uncertainty regarding the availability of critical instructional supports—including classroom or laboratory space, sufficient time to teach, personal knowledge, textbooks, planning time, student academic ability, scientific equipment, and instructional materials—indicating neutral or inconsistent access (M = 2.51–3.50). These findings highlight that while general resources are available, the most essential hands-on, time-based, and content-specific supports required for effective biotechnology instruction remain inadequate, revealing significant barriers and underscoring the need for targeted resource investments and professional development.

Lesson & Curriculum Information Resources

Teachers reported minimal use of formal instructional support sources, indicating that workshops (PLUs or industry-based), university courses, and artificial intelligence tools were never used for biotechnology curriculum development. Instead, premade lesson plans served as the most frequently used resource each semester, demonstrating reliance on readily accessible, ready-to-implement materials rather than structured professional training. This pattern suggests that while teachers participate in professional development, they perceive its primary benefit as receiving premade lessons rather than gaining broader instructional improvement—implying that professional development must be more practical, directly applicable, and agriculture-specific to be effective. The current disconnect between general science-based professional development offerings and agricultural classroom realities appears to require teachers to make significant instructional leaps on their own, limiting the overall usefulness and impact of professional development experiences. Use of social media teacher groups was inconsistent, with responses split between monthly use and never use, suggesting uneven access or trust in these platforms. Peer collaboration remained a primary source of support, as other agriculture teachers were used monthly for biotechnology information, emphasizing the critical role of teacher-to-teacher networks in addressing curriculum needs.

Student Characteristics

Teachers strongly agreed that students prefer hands-on learning experiences over traditional instruction ($M = 4.60$), and they perceived students as having active supervised agricultural experiences (SAEs) and a functional understanding of the scientific method (M ≈ 3.7–3.8). However, teachers were neutral across twelve of the sixteen student characteristics measured, indicating uncertainty about students' readiness, interest, or ability to succeed in biotechnology-related coursework. The lowest agreement was that students receive adequate support for learning at home (M = 2.47), and teachers also expressed concerns about students' critical thinking skills, motivation, and prioritization of school responsibilities, reflecting additional barriers to biotechnology instruction.

Community Characteristics

Teachers agreed that their communities provide general support for agricultural education programs, agriculture, teaching, and student SAE projects (M = 3.53–3.90), indicating a positive baseline environment for program success. However, neutrality across nine additional items suggested inconsistent or limited engagement with agricultural education beyond traditional program elements. Communities were perceived as lacking awareness about biotechnology (M = 2.67) and slow to adopt new innovations (M = 2.60), reflecting a potential barrier to expanding biotechnology instruction and workforce development alignment.

Recommendations for Future Research

Future research should examine how Georgia agricultural education teachers currently develop or obtain biotechnology instructional materials, especially given the broad and ambiguous nature of state standards, and investigate whether more explicit, modernized biotechnology standards would promote meaningful classroom implementation.

Additional studies are needed to explore external factors—including resource availability, student characteristics, and community influences—that impact biotechnology integration, as well as to identify targeted professional development needs within Plant Science & Biotechnology and Animal Science & Biotechnology courses.

Research should also evaluate the accuracy and relevance of existing curriculum resources on the Georgia Agricultural Education website and assess student-based barriers such as proficiency in science and mathematics and critical thinking skills.

Expanding this study to other states would help determine nationwide trends in biotechnology adoption within agricultural education, while examining community perceptions may inform outreach strategies to build public understanding and support.

Finally, future research should investigate the relationship between teacher characteristics and implementation of success to explore ways in which teacher education programs can better prepare pre-service educators to teach advanced biotechnology concepts.

Recommendations for Practice

To strengthen biotechnology instruction in Georgia agricultural education, state content standards should be revised to incorporate modern biotechnology terminology and applications, replacing the broad language established in 2013–2014 with clearer and more focused expectations aligned to national AFNR standards. If immediate revision is not feasible, existing resources on the Georgia Agricultural Education website should be evaluated for accuracy and relevance, supported by the creation of a state-level taskforce to continually update biotechnology teaching materials.

Enhanced professional development is essential, particularly in advanced molecular content areas such as recombinant DNA, gene splicing, transgenic species, microbial biotechnology, and genetic engineering. Maintaining rigorous biotechnology coursework is critical to justify continued approval as a fourth science credit, requiring stronger teacher preparation programs that emphasize technical knowledge and instructional confidence.

Increased interdisciplinary collaboration between agricultural and science educators, along with intentional community engagement initiatives, will support improved student scientific literacy and broader public understanding of biotechnology in agricultural education.

References

Advance CTE. (2020). *Without limits: A shared vision for the future of career technical education*. www.careertech.org/without-limits

Ary, D., Jacobs, L.C., Sorensen, C.K. and Walker, D. (2014) *Introduction to Research in Education*. 9th Edition, Wadsworth, Cengage Learning.

Bailey, L .H. (1904). What is Agricultural Education?, In L. H. Bailey (Eds.), *Cornell Nature Study Leaflets* (pp 45 – 54). J. B. Lyon Company Printers.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Prentice-Hall.

Bandura, A. (1997). *Self-efficacy: The exercise of control.* W. H. Freeman.

Biotechnology Innovation Organization. (2020). *The U.S. bioscience economy: Driving economic growth and opportunities in states and regions*. https://bio.widen.net/s/hflmb92hwx/the-us-bioscience-economy-driving-economic-growth-and-opportunities-in-states-and-regions?utm.com

Boone, H. N., Gartin, S. A., Boone, D. A., & Hughes, J. E. (2006). Modernizing the agricultural education curriculum: an analysis of agricultural education teachers' attitudes, knowledge, and understanding of biotechnology. *Journal of Agricultural Education*, *47*(1), 78–89. https://doi.org/10.5032/jae.2006.01078

Borich, G. D. (1980). A needs assessment model for conducting follow-up studies. *Journal of Teacher Education*, *31*(3), 39–42. https://doi.org/10.1177/002248718003100310

Budke, W. E. (1991). Agriculture science- Striving for excellence. T*he Agricultural Education Magazine, 63*(7), 4, 11. https://www.naae.org/naae/document-server/?cfp=/naae/assets/file/public/magazine/volume63/v63i7.pdf

Caillouet, O., & Harder, A. (2022). *Conducting the needs assessment #8: The Borich model* (Publication WC415). University of Florida IFAS Extension. https://edis.ifas.ufl.edu/publication/WC415

Chang, C., & Lindner, J. R. (2017). Taiwanese Smallholder Farmers' Perceptions and Barriers to Adopting Facebook. *Journal of International Agricultural and Extension Education, 24*(3), 36-51. DOI: https://doi.org/10.5191/jiaee.2017.24304

Chen, S. Y., & Raffin, J. (1999). Biotechnology: Student's knowledge and attitudes in the UK and Taiwan. *Journal of Biological Education*, *34*(1), 17-23. https://doi.org/10.1002/bmb.20969

Chiasson, T. C., & Burnett, M. F. (2001). The influence of enrollment in agriscience courses on the science achievement of high school students. *Journal of Agricultural Education*, *42*(1), 61–71. https://doi.org/10.5032/jae.2001.01061

Christian, T., & Key, J. P. (1994). *Agriscience equal to science*. (Eric Document Reproduction Service No. ED 334421) https://files.eric.ed.gov/fulltext/ED334421.pdf

Clemons, C., Lindner, J. R., Murray, B., Cook, M. P., Sams, B., & Williams, G. (2018). Spanning the Gap: The Confluence of Agricultural Literacy and Being Agriculturally Literate. *Journal of Agricultural Education*, *59*(4), 238–252. https://doi.org/10.5032/jae.2018.04238

Croom, D. B. (2008). The development of the integrated three-component model of agricultural education. *Journal of Agricultural Education, 49*(1), 110–120. https://doi.org/10.5032/jae.2008.01110

DiBenedetto, C. A. (2015). *Teachers' perceptions of their proficiency and responsibility to teach the knowledge, skill, and dispositions required of high school students to be career ready in the 21st century* [Doctoral dissertation, University of Florida]. University of Florida Institutional Repository. https://files.eric.ed.gov/fulltext/EJ1249819.pdf

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). *Internet, phone, mail, and mixed mode surveys: The tailored design method* (4th ed.). John Wiley & Sons, Inc.

Dooley, K. E., & Lindner, J. R. (2002). Competency-based behavioral anchors as authentication tools to document distance education competencies. *Journal of Agricultural Education*, *43*(1), 24–35. https://doi.org/10.5032/jae.2002.01024

Enderlin, K. J., & Osborne, E. W. (1992). *Student achievement, attitudes, and thinking skill attainment in an integrated science/agriculture course* [Paper presentation]. National Agricultural Education Research 19th Annual Meeting, St. Louis, MO, United States. https://cdn.agclassroom.org/ncal/research/influential/summaries_research.pdf

ERC Association. (n.d.). *CMaT partnership with Georgia Bio establishes rural teacher training initiative to build a biomanufacturing workforce.* https://erc-assoc.org/achievement/cmat-partnershipgeorgia-bio-establishes-rural-teacher-training-initiative-build?utm.com

Faulk, B. McKibben, J. D., Clemons, C. A., & Lindner, J. R. (2024). Instructor Levels of Importance and Competence with Alabama Agricultural Mechanics Standards. Journal of Southern Agricultural Education Research, 74(1). http://jsaer.org/wpcontent/uploads/2024/12/74-Faulk-McKibben-Clemons-Lindner.pdf

Field, A. (2013). Discovering Statistics Using IBM SPSS Statistics: and Sex Drugs and Rock 'n' Roll. Sage.

Food and Agriculture Organization of the United Nations. (2009). *Proceedings of the Expert Meeting on How to Feed the World in 2050.* Food and Agriculture Organization. https://www.fao.org/4/ak542e/ak542e00.htm?utm.com

Fort Valley State University. (2006). *Educating the Educators: "The Future Is Now" through AgBiotechnology Education Enrichment for K-12 school teachers* [Project summary]. National Institute of Food and Agriculture. https://portal.nifa.usda.gov/web/crisprojectpages/0198054-educating-the-educators-the-future-is-now-through-agbiotechnology-education-enrichment-for-k-12-school-teachers.html?utm.com

Fraenkel, J. R., Wallen, N. E., Hyun, H. H. (2019) *How to Design and Evaluate Research in Education* (10th ed.). McGraw-Hill Education.

Georgia Administrative Code, Rule 160-4-2-.03, List of State-Funded K-8 Subjects and 9-12 Courses for Students Entering Ninth Grade Prior to 2008. (1990 & rev. 2011). https://rules.sos.state.ga.us/gac/160-4-2-.03

Georgia BioEd Institute. (n.d.). *Biotech Teacher Training Initiative*. https://www.galifesciences.org/biotech-teacher-training-initiative

Georgia Department of Education. (n.d.). *Browse standards – CTAE: Agriculture, Food & Natural Resources*. https://case.georgiastandards.org/8d5c9983-ba6c-4dc4-849e-df2575c9745b/8d5c9983-ba6c-4dc4-849e-df2575c9745b

Georgia Department of Education. (n.d.). *Career Clusters/Pathways.* https://www.gadoe.org/Curriculum-Instruction-and-Assessment/CTAE/Pages/CTAE-Georgia-Career-Clusters.aspx

Georgia FFA Association. (n.d. a). *Georgia AFNR Standards*. https://georgiaffa.org/page.aspx?ID=125&utm.com

Georgia FFA Association. (n.d. b). *Animal science and biotechnology curriculum standards.* https://georgiaffa.org/curriculum/topic.aspx?TID=11

Georgia FFA Association. (n.d. c). *Plant science and biotechnology curriculum standards*. https://www.georgiaffa.org/curriculum/topic.aspx?TID=27&utm.com

Georgia General Assembly, Senate Research Office. (n.d.). *Agricultural education* [Study Committee Report No. 10]. https://www.senate.ga.gov/sro/Documents/StudyCommRpts/10AgEd.pdf

Georgia Public Broadcasting. (n.d.). *Georgia Standards of Excellence (GSE)*. https://www.gpb.org/education/standards

Georgia Student Finance Commission. (n.d.). *Georgia graduation requirements*. https://www.gafutures.org/college-planning/college-decision-guide/graduation-requirements/

Griffin, G. S., & Kieffer, L. (2023). *23-13 SE education standards: Final draft (Special Examination Report No. 23-13)*. Georgia Department of Audits and Accounts, Performance Audit Division. https://www.audits.ga.gov/ReportSearch/download/30518

Hancock, G. T., Hancock, C. E., & McKibben, J. D. (2024). The Teaching Techniques of Alabama's Traditionally and Alternatively Certified School-Based Agricultural Education Instructors. *Journal of Agricultural Education*, *65*(3), 18–34. https://doi.org/10.5032/jae.v65i3.166

Hanagriff, R. D., Murphy, T. H., Roberts, T. G., Briers, G. E., & Lindner, J. R. (2010). Economic Impact of Supervised Agricultural Experiences: Returns from SAE Investment Costs in Texas, 2007–2008. *Journal of Agricultural Education*, *51*(4), 71–81. https://doi.org/10.5032/jae.2010.04071

Harder, A., & Lindner, J. R. (2008). Going global with Extension: Barriers to the adoption of a web-based resource. *Journal of International Agricultural and Extension Education*, *15*(3), 69-80.

Harder, A., Ganpat, W., Moore, A., Strong, R., & Lindner, J. R. (2013). An Assessment of Extension Officers' Self-Perceived Programming Competencies in Selected Caribbean Countries. *Journal of International Agricultural and Extension Education, 20*(1), 33-46. DOI: https://doi.org/10.4148/2831-5960.1244

Harmon, R. L., & Paul, J. H. (2020). Current status of research, regulations, and future challenges for CRISPR gene editing in crop improvement. *UF/IFAS Extension*, *HS1315*. https://edis.ifas.ufl.edu/publication/HS1315?downloadOpen=true

Hatch Act, 7 U.S.C. § 361a *et seq*. (1887). https://uscode.house.gov/view.xhtml?req=(title:7%20section:361a%20edition:prelim

Hendrix, R., McKibben, J., & Swortzel, K. (2024). Agricultural Educators' Personal Teaching Efficacy Towards Individual STEM Subjects. *Journal of Agricultural Education*, *65*(2), 306–321. https://doi.org/10.5032/jae.v65i2.2383

Hillison, J. (1996). The origins of agriscience: or where did all that scientific agriculture come from?. *Journal of Agricultural Education*, *37*(4), 8–13. https://doi.org/10.5032/jae.1996.04008

Holmes, C. (2003). *UGA to offer applied biotechnology major* [Field Report]. University of Georgia College of Agricultural & Environmental Sciences. https://fieldreport.caes.uga.edu/news/uga-to-offer-applied-biotechnology-major/

Hummel, W. G, & Hummel, B. R. (1913). *Materials and Methods in High School Agriculture*. McMillan Company.

International Service for the Acquisition of Agri-biotech Applications. (n.d.). *Biotech in agriculture: Timeline.* https://www.isaaa.org/kc/inforesources/publications/biotechinagriculture/default.html#Biotech_Timeline_.htm?utm

Khan, A., Ali, A., Khan, H., & Amin, M. (2021). CRISPR/Cas: The new frontier in plant improvement. *ACS Agricultural Science & Technology*, *1*(5), 388–397. https://doi.org/10.1021/acsagscitech.1c00279

Lambert, M. D., Velez, J. J., & Elliott, K. M. (2014). What are the teachers' experiences when implementing the Curriculum for Agricultural Science Education? *Journal of Agricultural Education*, *55*(4), 100–115. https://doi.org/10.5032/jae.2014.04100

Li, Y., & Lindner, J. R. (2007). Barriers to diffusion of web-based distance education at China Agricultural University. *Journal of International Agricultural and Extension Education*, *14*(1), 45-57.

Lindner, J. R., & Lindner, N. (2024). Interpreting Likert type, summated, unidimensional, and attitudinal scales: I neither agree nor disagree, Likert or not. *Advancements in Agricultural Development*, *5*(2), 152–163. https://doi.org/10.37433/aad.v5i2.351

Lindner, J. R., Murphy, T. H., & Briers, G. E. (2001). Handling Nonresponse in Social Research. *Journal of Agricultural Education*, *42*(4), 43–53. https://doi.org/10.5032/jae.2001.04043

Lindner, J. R. (2002). Handling of non-response in the Journal of International Agricultural and Extension Education. *Journal of International Agricultural and Extension Education*, *9*(3), 55-60. https://doi.10.5191/jiaee.2002.09307

Lindner, J. R., Dooley, K. E., & Murphy, T. H. (2001). Differences in competencies between doctoral students on-campus and at a distance. *American Journal of Distance Education*, *15*(2), 25–40. https://doi.org/10.1080/08923640109527082

Lindner, J. R., Rodriguez, M. T., Strong, R., Jones, D., & Layfield, D. (2016). Research priority area 2: New technologies, practices, and products adoption decisions. American Association for Agricultural Education National Research Agenda, 2020, 19-27. https://aaea.wildapricot.org/resources/Documents/AAAE_National_Research_Agenda_2016-2020.pdf

Malpiedi, B. J. (1989). Agriscience and emerging technologies: Today's science, tomorrow's agriculture. *Agricultural Education Magazine*, *61*(8), 4–5. https://www.naae.org/naae/document-server/cfp=/naae/assets/file/public/magazine/volume61/v61i8.pdf

McKibben, J. D., & Murphy, T. H. (2021). The Effect of Authenticity on Project-Based Learning: A Quasi-Experimental Study of STEM Integration in Agriculture. *Journal of Agricultural Education*, *62*(1), 144–155. https://doi.org/10.5032/jae.2021.01144

McKibben, J. D., Clemons, C. A., & Blythe, J. M. (2025). Survey response rates by requestor's characteristics. *Advancements in Agricultural Development*, *6*(1), 43–54. https://doi.org/10.37433/aad.v6i1.525

McKibben, J., Hancock, G., Clemons, C., & Murphy, T. (2024). Effects of Novelty on Project-Based Methods when Integrating Physics into Agriculture Courses. *Journal of Agricultural Education*, *65*(2), 86–98. https://doi.org/10.5032/jae.v65i2.126

McKibben, J., Holler, K., Clemons, C., & Lindner, J. (2023). Locus of Control and Pedagogy in Skill-Based Agricultural Mechanics. *NACTA Journal*, *67*(1). https://doi.org/10.56103/nactaj.v67i1.88

Mowen, D. L., Roberts, T. G., Wingenbach, G. J., & Harlin, J. F. (2007). Biotechnology: an assessment of agricultural science teachers' knowledge and attitudes. *Journal of Agricultural Education*, *48*(1), 42–51. https://doi.org/10.5032/jae.2007.01042

National Council on Vocational Education (1990). *Occupational Competencies. A Study of the Vocational-Technical Education Needs of the Agribusiness and Chemistry-Based Technology Industries* [electronic resource]. Distributed by ERIC Clearinghouse. https://files.eric.ed.gov/fulltext/ED318861.pdf

National FFA Foundation. (1994). *National voluntary occupational skills standards: Agricultural biotechnology technician*. National FFA Foundation, Alexandria, VA. https://files.eric.ed.gov/fulltext/ED413487.pdf

National FFA Organization. (2025, January 13). *1988*. National FFA Organization. https://www.ffa.org/timeline/1988/

National FFA Organization. (n.d.). *About FFA*. https://www.ffa.org/about/

National FFA Organization. (n.d.). *Agricultural Education*. https://www.ffa.org/agricultural-education/

National Research Council. (2009). *A new biology for the 21st century*. Washington, DC: The National Academies Press. https://doi.org/10.17226/12764

National Resource Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press. https://doi.org/10.17226/12165

Newman, M. E., & Johnson, D. M. (1994). Inservice Education Needs of Teachers of Pilot Agriscience Courses in Mississippi. *Journal of Agricultural Education*, *35*(1), 54–60. https://doi.org/10.5032/jae.1994.01054

Phipps, L. J., Osborne, E. W., Dyer, J. E., & Ball, A. L. (2008). *Handbook on agricultural education in the public schools*. Thomson Delmar Learning.

Pollard, M. (2020) *A historical analysis of the 2020 agricultural education vision plan and the reformation of agricultural education in Georgia as it intended*. (Publication No. 181) [Doctoral dissertation, Murray State University]. Murray State's Digital Commons. https://digitalcommons.murraystate.edu/etd/181

Ray, B. L., Clemons, C. A., McKibben, J. D., Lindner, J. R., Fuhrman, N. E., & Barlow, R. J. (2022). Implementing Forestry and Natural Resource Curricula in Georgia. A Quantitative Analysis of Perceived Barriers Towards Implementation. *Journal of Agricultural Education*, *63*(3), 149–165. https://doi.org/10.5032/jae.2022.03149

Roegge, C. A., & Russell, E. B. (1990). Teaching applied biology in secondary agriculture: effects on student achievement and attitudes. *Journal of Agricultural Education*, *31*(1), 27-31. https://doi.org/10.5032/jae.1990.01027

Rogers, E. M. (2003). *Diffusion of Innovations*. Free Press, New York.

Scott, J. D., Bird, T. D., Rubenstein, E. D., & Kvitko, B. H. (2025). Examining the Implementation of Plant Pathology Curricula in School-Based Agricultural Education: A

Pilot Study. *Journal of Agricultural Education*, *66*(3), Article 25. https://doi.org/10.5032/jae.v66i3.3035

Steele, F., & Aubusson, P. (2004). The challenge in teaching biotechnology. *Research in Science Education*, *34*, 365-387. https://doi.org/10.1007/s11165-004-0842-1

Stewart, R. M., & Getman, A. K. (1927). *Teaching Agricultural Vocations.* John Wiley & Sons, Inc.

Stimson, R. W. (1942). Historic Background Common to All States. In R. W. Stimson & F. W. Lathrop (Eds.), *History of Agricultural Education of Less than College Grade in the United States.* (pp1 – 8). Bulletin Prepared for the U. S. Office of Education, Federal Security Agency.

The National Council for Agricultural Education. (2023). *AFNR standards*. https://thecouncil.ffa.org/afnr/

Thompson, G. W. (2001). Perceptions of oregon secondary principals regarding integrating science into agricultural science and technology programs. *Journal of Agricultural Education*, *42*(1), 50–60. https://doi.org/10.5032/jae.2001.01050

Thompson, G. W., & Warnick, B. K. (2007). Integrating science into the agricultural education curriculum: do science and agriculture teachers agree?. *Journal of Agricultural Education*, *48*(3), 1–12. https://doi.org/10.5032/jae.2007.03001

U.S. Department of Agriculture. (n.d.). *Biotechnology FAQs*. https://www.usda.gov/farming-and-ranching/plants-and-crops/biotechnology/biotechnology-faqs

U.S. Food and Drug Administration. (n.d.). *Food ingredient & packaging terms: Biotechnology*. https://www.fda.gov/food/food-ingredients-packaging/food-ingredient-packaging-terms?utm_

Ufnar, J. A., & Shepherd, V. L. (2018). The scientist in the classroom partnership program: an innovative teacher professional development model. *Professional Development in Education*, *45*(1), 642–658. https://doi.org/10.1080/19415257.2018.1474487

Vaughn, P. R. (1993). Teaching agriscience: A few cautions. *The Agricultural Education Magazine*, *66* (4), 4. https://www.naae.org/naae/document-server/?cfp=/naae/assets/file/public/magazine/volume66/v66i7.pdf

Williams, J., McKibben, J. D., Clemons, C., Cletzer, D. A., Lindner, J. R. (2025). The Impacts of Balance, Engagement, and Commitment of Alabama SBAE Retention. Proceedings of the 2025 AAAE-Southern Region. https://doi.org/10.13140/RG.2.2.24688.57600

Wilson, E., Kirby, B., & Flowers, J. (2002). Factors influencing the intent of north carolina agricultural educators to adopt agricultural biotechnology curriculum. *Journal of Agricultural Education*, *43*(1), 69–81. https://doi.org/10.5032/jae.2002.01069

Yamane, T. (1967), *Statistics: An Introductory Analysis* (2nd Edition). Harper & Row. https://archive.org/details/statisticsanintr0000taro/page/n7/mode/2up

Zaidi, S. S.-e.-A., Vanderschuren, H., Qaim, M., Mahfouz, M. M., Kohli, A., Mansoor, S., & Tester, M. (2020). Engineering crops of the future: CRISPR approaches to develop climate-resilient and disease-resistant plants. *Genome Biology*, *21*(1), 289. https://doi.org/10.1186/s13059-020-02204-y

Zhang, X., & Liu, H. (2024). Genetic modification techniques in plant breeding: A comparative review of CRISPR/Cas and GM technologies. *Horticultural Plant Journal*, *10*(3), 212–225. https://doi.org/10.1016/j.hpj.2024.05.002

Appendices

Appendix A: Instrument

AUBURN UNIVERSITY

My name is Lissi Chism, a fellow ag teacher in Georgia who mostly taught biotechnology, and I am conducting research as part of my doctoral degree at Auburn University. To not overburden ag teachers, I am only asking a few specific people to answer this short survey and because of **your expertise**, I would very much like your opinions. I am trying to capture your beliefs about what should be taught in biotechnology and your ability to teach those topics in biotechnology. The results will help us better understand how to support the teaching of biotechnology within agriculture and advocate for agricultural education in Georgia.

Thank you for VOLUNTEERING your help in this crucial research!

By continuing, you are indicating your informed consent to participate in the research.

For more information, see: BioTech_GA_AG_info_letter

Gender:

- ○ Male
- ○ Female
- ○ Not Listed

What year were you born?

What was your path to certification?

- ○ Undergraduate student teaching
- ○ Graduate student teaching
- ○ Industry credential/certification
- ○ Other

What is your ethnicity?

- ○ American Indian or Alaska Native
- ○ Asian
- ○ Black or African American
- ○ Native Hawaiian or Pacific Islander
- ○ White
- ○ Not listed

Please indicate your highest level of education and area of study.

Technical/Trades School	
Bachelor's Degree	
Master's Degree	
Specialist's Degree	
Doctoral Degree	

How many years (as of the end of June 2025) have you been a teacher?

- I am starting my first year
- 1-5
- 6-10
- 11-15
- 16-20
- 21-25
- 26-30
- >30

How many years (including the current year) have you been an **Ag teacher**?

- ○ I am starting my first year
- ○ 1-5
- ○ 6-10
- ○ 11-15
- ○ 16-20
- ○ 21-25
- ○ 26-30
- ○ >30

If you were forced to pick only ONE, what would be your area of specialty in Agricultural Education?

- ○ Ag Mechanics
- ○ Animal Science
- ○ Biotechnology
- ○ FFA
- ○ Field Crop Production
- ○ Forestry
- ○ Horticulture
- ○ Personal Development
- ○ Soils
- ○ Other
- ○ None

What is your school's zip code?

What content area certification(s) do you currently hold?

- ☐ Agriculture
- ☐ CTE other than Agriculture
- ☐ Early Childhood/Elementary
- ☐ English Language Arts
- ☐ Fine Art (any)
- ☐ Foreign Language (any)
- ☐ Mathematics Physical
- ☐ Education Science (any)
- ☐ Social Studies (any)
- ☐ Special Education (any)
- ☐ Other:

Overall, how important is a standalone agricultural biotechnology course?

- ○ Not important
- ○ Somewhat not important
- ○ Neither Important nor not important
- ○ Somewhat important
- ○ Very important

How important are the following topics for a student in your courses to learn by the end of the course

	Not important	Somewhat not important	Neither Important nor not important	Somewhat important	Very important
Recombinant DNA	○	○	○	○	○
Gene Splicing	○	○	○	○	○
Genetic Engineering	○	○	○	○	○
Cloning	○	○	○	○	○

Transgenic Species	○	○	○	○	○
Genetically Modified Food	○	○	○	○	○
Biotechnology Laboratory Techniques	○	○	○	○	○
Environmental Biotechnology	○	○	○	○	○
Food Biotechnology	○	○	○	○	○
Microbial Biotechnology	○	○	○	○	○
Hybridization	○	○	○	○	○
Plant Tissue Culture	○	○	○	○	○
Resistant Plant Species	○	○	○	○	○
Animal Reproduction	○	○	○	○	○
Growth Hormones (bST, pST, GAs, CKs, etc.)	○	○	○	○	○
Biotechnology Ethics	○	○	○	○	○
Diseases	○	○	○	○	○
Plant Reproduction	○	○	○	○	○
Classification	○	○	○	○	○

Generally, how knowledgeable do you feel about biotechnology in agriculture?

- ○ I have no knowledge
- ○ I have some knowledge
- ○ I am knowledgeable
- ○ I am fairly knowledgeable
- ○ I have a lot of knowledge

Please indicate ***YOUR*** level of knowledge about the following topics

	I have no knowledge	I have some knowledge	I am knowledgeable	I am fairly knowledgeable	I have a lot of knowledge
Recombinant DNA	○	○	○	○	○
Gene Splicing	○	○	○	○	○
Genetic Engineering	○	○	○	○	○
Cloning	○	○	○	○	○
Transgenic Species	○	○	○	○	○
Genetically Modified Food	○	○	○	○	○

Biotechnology Laboratory Techniques	○	○	○	○	○
Environmental Biotechnology	○	○	○	○	○
Food Biotechnology	○	○	○	○	○
Microbial Biotechnology	○	○	○	○	○
Hybridization	○	○	○	○	○
Plant Tissue Culture	○	○	○	○	○
Resistant Plant Species	○	○	○	○	○
Animal Reproduction	○	○	○	○	○
Growth Hormones (bST, pST, GAs, CKs, etc.)	○	○	○	○	○
Biotechnology Ethics	○	○	○	○	○
Diseases	○	○	○	○	○
Plant Reproduction	○	○	○	○	○
Classification	○	○	○	○	○

Generally, how competent do you feel about teaching biotechnology in agriculture?

- ○ I do not feel competent at all
- ○ I feel mostly not competent
- ○ I am neither competent nor not competent
- ○ I feel mostly competent
- ○ I am competent

How competent do you feel to teach each of the following topics in your courses?

	I do not feel competent at all	I feel mostly not competent	I feel neither competent nor not competent	I feel mostly competent	I am competent
Recombinant DNA	○	○	○	○	○
Gene Splicing	○	○	○	○	○
Genetic Engineering	○	○	○	○	○
Cloning	○	○	○	○	○
Transgenic Species	○	○	○	○	○
Genetically Modified Food	○	○	○	○	○

Biotechnology Laboratory Techniques	○	○	○	○	○
Environmental Biotechnology	○	○	○	○	○
Food Biotechnology	○	○	○	○	○
Microbial Biotechnology	○	○	○	○	○
Hybridization	○	○	○	○	○
Plant Tissue Culture	○	○	○	○	○
Resistant Plant Species	○	○	○	○	○
Animal Reproduction	○	○	○	○	○
Growth Hormones (bST, pST, GAs, CKs, etc.)	○	○	○	○	○
Biotechnology Ethics	○	○	○	○	○
Diseases	○	○	○	○	○
Plant Reproduction	○	○	○	○	○
Classification	○	○	○	○	○

Generally, do you have enough resources to teach biotechnology in agriculture?

- ◯ I have more than enough
- ◯ I have enough
- ◯ I could use a little more, but it's not hindering me
- ◯ I have some, but not enough
- ◯ I do not have any

Please indicate if you have enough of the following to **teach** biotechnology successfully.

	I have more than enough	I have enough	I could use a little more, but it's not hindering me	I have few, and it is hindering me	I do not have any
Scientific/Lab Equipment	◯	◯	◯	◯	◯
Information Technology (computers, tablets, etc..)	◯	◯	◯	◯	◯
Instructional Materials	◯	◯	◯	◯	◯

Textbooks/Physical Curriculum	○	○	○	○	○
Student Academic Ability	○	○	○	○	○
Personal (teacher) Knowledge	○	○	○	○	○
Time to plan	○	○	○	○	○
Time to teach	○	○	○	○	○
Classroom/Lab space	○	○	○	○	○
Administration Support	○	○	○	○	○
Internet/Connectivity	○	○	○	○	○

Please indicate if you have how often you successfully use the following to **<u>teach</u>** biotechnology.

	Daily	Weekly	Monthly	Each Semester	Once a year	Never
Workshops (PLUs/education based)	○	○	○	○	○	○
Workshops (Industry-led)	○	○	○	○	○	○
University Courses	○	○	○	○	○	○
Pre-made lesson plans	○	○	○	○	○	○
Social Media Teacher Groups	○	○	○	○	○	○
Other Ag Teachers	○	○	○	○	○	○
Artificial Intelligence	○	○	○	○	○	○

Please indicate your level of agreement with the following statements

My students....

	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree
... have good access to the internet at home.	○	○	○	○	○
... have enough time at home to study.	○	○	○	○	○
... have the support at home they need to learn.	○	○	○	○	○
... have a strong desire to learn.	○	○	○	○	○
... have a passion for agriculture.	○	○	○	○	○
... want to learn the science of agriculture.	○	○	○	○	○
... can read well enough to do well in my class.	○	○	○	○	○
... understand math well enough to do well in my class.	○	○	○	○	○
... understand science well enough to do well in my class.	○	○	○	○	○
... have the study skills they need to be successful in my class.	○	○	○	○	○
... prioritize school.	○	○	○	○	○
... have active SAEs.	○	○	○	○	○
... have SAEs that relate to the class they are taking currently.	○	○	○	○	○

... understand the basics of the scientific method.	○	○	○	○	○
... have critical thinking skills to figure out solutions to problems.	○	○	○	○	○
... prefer the hands-on learning aspect of agriculture compared to traditional methods of learning.	○	○	○	○	○

Please indicate your level of agreement with the following statements

My community....

	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree
... has an accurate view of agriculture.	○	○	○	○	○
... has an accurate view of biotechnology.	○	○	○	○	○
... supports teaching.	○	○	○	○	○
... supports agriculture.	○	○	○	○	○
... is academically progressive.	○	○	○	○	○
... is quick to adopt new things.	○	○	○	○	○
... supports the ag program.	○	○	○	○	○
... wants me to teach biotechnology.	○	○	○	○	○
... sees a future in agriculture for the community.	○	○	○	○	○
... sees a future in agriculture for the students.	○	○	○	○	○
... supports individual students SAE projects.	○	○	○	○	○
... understands that agricultural education enriches the learning of core subjects.	○	○	○	○	○
... engages in adult and community education and other programs hosted by the ag program.	○	○	○	○	○

Appendix B: IRB Approval

AUBURN UNIVERSITY
Institutional Review Board

EXEMPT DETERMINATION

April 6, 2025

Jason McKibben
Haley Center 5040
Auburn Univ, AL 36849

3348444434
jdm0184@auburn.edu

Dear Jason McKibben:

On 4/6/2025, the IRB reviewed the following submission:

Protocol Information	Submission Details
Type of Review:	Initial Study
Title:	Biotechnology in School Based Agricultural Education of Georgia
Investigator:	Jason McKibben
IRB ID:	STUDY00000464
Funding:	None
Grant Title:	N/A
Grant ID:	None
IND, IDE or HDE:	None
Documents Reviewed:	• Biotech instrument , Category: Survey/Questionnaire; • information letter, Category: Consent Form; • L Chism protocol , Category: IRB Protocol; • post card blurb, Category: Recruitment Materials;

The IRB determined that this protocol meets the criteria for exemption from IRB review.

In conducting this protocol you are required to follow the requirements listed in HRP-103 - INVESTIGATOR MANUAL.

To maintain an accurate account of active human research studies at AU, exempt determinations will require renewal or closure after 3 years. This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these activities impact the exempt determination, please submit a new request to the IRB for a determination.

AUBURN UNIVERSITY
Institutional Review Board

Sincerely,

IRB Administration
540 Devall Drive
Auburn, AL 36849
irbadmin@auburn.edu
(334) 844-5966

INFORMATION LETTER

Title of research study: *Biotechnology in School Based Agricultural Education of Georgia*

Investigator: *Lissi Chism and Jason McKibben*

You are invited to participate in a research study to evaluate teachers' beliefs about their ability to teach biotechnology topics in school-based agricultural education in Georgia. The study is being conducted by Lissi Chism under the direction of Jason McKibben in the Auburn University Department of Agricultural Education. You were selected as a possible participant because you are currently listed as teaching a course on biotechnology in an agricultural pathway**.**

***What will be involved if you participate*?** If you decide to participate in this research study, you will be asked to complete the survey instrument as best you can. Your total time commitment will be approximately 8 minutes.

Are there any risks or discomforts? The risks associated with participating in this study are no more than would be seen in your normal day and the primary risk is the loss of anonymity.

Are there any benefits to yourself or others? If you participate in this study, you cannot expect any direct compensation or benefit, but we hope to use these results to help inform best practice and professional development for agriculturists like you.

Are there any costs? If you decide to participate, the only thing it will cost you is, at most, eight minutes of your time.

If you change your mind about participating, you can withdraw at any time during the study. Your participation is completely voluntary. If you choose to withdraw, your data can be withdrawn as long as it is identifiable. Your decision about whether or not to participate or to stop participating will not jeopardize your future relations with Auburn University, the Department of Curriculum and Teaching or Agricultural Education.

Any data obtained in connection with this study will remain confidential. We will protect your privacy and the data you provide by keeping all results secure in accordance with Auburn University and IRB rules. Information collected through your participation may be (e.g., used to fulfill an educational requirement, published in a professional journal, and/or presented at a professional meeting, etc.). Any reports or documents produced will be done so with deidentified aggregated data**.**

If you have questions about this study, please ask them now or contact Lissi Chism at lgc0043@auburn.edu or Jason McKibben at jdm0184@auburn.edu

If you have questions about your rights as a research participant, you may contact the Auburn University Office of Research Compliance or the Institutional Review Board by phone (334) 844-5966 or e-mail at IRBadmin@auburn.edu or IRBChair@auburn.edu.

HAVING READ THE INFORMATION PROVIDED, YOU MUST DECIDE IF YOU WANT TO PARTICIPATE IN THIS RESEARCH PROJECT. IF YOU DECIDE TO PARTICIPATE, THE DATA YOU PROVIDE WILL SERVE AS YOUR AGREEMENT TO DO SO. THIS LETTER IS YOURS TO KEEP.

Appendix C: Recruitment Materials

Initial Email

Hey ${e://Field/RecipientFirstName} ,
My name is Lissi Chism, and I'm a fellow Ag Biotech teacher in Georgia. I'm reaching out to personally invite you to participate in research focused on Georgia Agriculture Teachers who teach BioTechnology.
The research is designed to evaluate teachers' beliefs about what topics matter or which ones do not, as well as their ability to teach those biotechnology topics. The results will help in better understanding how to support the teaching of biotechnology within agriculture and how to advocate for our programs.

This is a request to you specifically, not a general listserv email, because ***your voice matters***.
Thank you for **volunteering** your time to support this important research.
You will have an instrument waiting at the Auburn Table at GVATA on Sunday and Monday for you to complete, but if you would like, you may complete it online now.

Best regards,
Lissi Chism

Follow this link to the Survey:
${l://SurveyLink?d=Take the survey}

Or copy and paste the URL below into your internet browser:
${l://SurveyURL}

Follow the link to opt out of future emails:
${l://OptOutLink?d=Click here to unsubscribe}

1st Reminder Email

Hey ${e://Field/RecipientFirstName} ,
My name is Lissi Chism, and I'm a fellow Ag Biotech teacher in Georgia. I'm reaching out to personally invite you to participate in research focused on Georgia Agriculture Teachers who teach BioTechnology.
${l://SurveyLink?d=Take the survey}

The research is designed to evaluate teachers' beliefs about what topics matter or which ones do not, as well as their ability to teach those biotechnology topics. The results will help in better understanding how to support the teaching of biotechnology within agriculture and how to advocate for our programs.

This is a request to you specifically, not a general listserv email, because ***your voice matters***. For those of you who have already completed this, THANK YOU!
Thank you for **volunteering** your time to support this important research.

Best regards,
Lissi Chism

Or copy and paste the URL below into your internet browser:
${l://SurveyURL}

Follow the link to opt out of future emails:
${l://OptOutLink?d=Click here to unsubscribe}

2nd Reminder Email

Hey ${e://Field/RecipientFirstName} ,

This is Lissi again. I know you get a ton of emails to complete surveys on our listserve. I do too. This isn't going out over the list serve for that reason to just anybody and everybody. It's going to just a few of YOU specifically ${e://Field/RecipientFirstName}. It's going to you because you are one of the few people like me who teach or have taught biotechnology in Georgia. I would very much like to be able to hear what you have to say about that experience and what we can do as a state to do better. ***Your voice matters,*** and with your answer, we are going to try to help make Ag better for all our kids.

THANK YOU for what you do for Georgia kids and what you do to promote agriculture!

Thank you for providing your voice to this effort to promote Ag in Georgia.

Follow this link to the Survey:
${l://SurveyLink?d=Take the survey}

Or copy and paste the URL below into your internet browser:
${l://SurveyURL}

Best regards,
Lissi Chism

3rd & Final Email

Hey ${e://Field/RecipientFirstName} ,
This is Lissi again. This isn't just another survey to get someone a degree; I am trying to help biotech teachers like us get what we need to help the kids. We get too many of these. I do too. This isn't going out to just anybody and everybody.
${e://Field/RecipientFirstName}, it's going to just a few of YOU specifically, because you are one of the few people, like me, who teach or have taught biotechnology.
THANK YOU for what you do for our kids and what you do to promote agriculture!
For all of you who have already completed, THANK YOU.

Follow this link to the Survey:
${l://SurveyLink?d=Take the survey}

Or copy and paste the URL below into your internet browser:
${l://SurveyURL}

Best regards,
Lissi Chism

Appendix D: Course Standards

Georgia Department of Education

Agriculture, Food & Natural Resources Career Cluster
Plant Science and Biotechnology
Course Number: 02.44100

Course Description:

Plant science is a basic component of the agriscience pathway. This course introduces students to the scientific theories, principles, and practices involved in the production and management of plants for food, feed, fiber, conservation and ornamental use. Classroom and laboratory activities are supplemented through supervised agricultural experiences and leadership programs and activities.

Course Standard 1

AFNR-PSB-1

The following standard is included in all CTAE courses adopted for the Career Cluster/Pathways. Teachers should incorporate the elements of this standard into lesson plans during the course. The topics listed for each element of the standard may be addressed in differentiated instruction matching the content of each course. These elements may also be addressed with specific lessons from a variety of resources. This content is not to be treated as a unit or separate body of knowledge but rather integrated into class activities as applications of the concept.

Standard: Demonstrate employability skills required by business and industry.

The following elements should be integrated throughout the content of this course.

1.1 Communicate effectively through writing, speaking, listening, reading, and interpersonal abilities.

Person-to-Person Etiquette	Telephone and Email Etiquette	Cell Phone and Internet Etiquette	Communicating At Work	Listening
Interacting with Your Boss	Telephone Conversations	Using Blogs	Improving Communication Skills	Reasons, Benefits, and Barriers
Interacting with Subordinates	Barriers to Phone conversations	Using Social Media	Effective Oral Communication	Listening Strategies
Interacting with Co-workers	Making and Returning Calls		Effective Written Communication	Ways We Filter What We Hear
Interacting with Suppliers	Making Cold Calls		Effective Nonverbal Skills	Developing a Listening Attitude
	Handling Conference Calls		Effective Word Use	Show You Are Listening
	Handling Unsolicited Calls		Giving and Receiving Feedback	Asking Questions
				Obtaining Feedback
				Getting Others to Listen

Nonverbal Communication	Written Communication	Speaking	Applications and Effective Résumés
Communicating Nonverbally	Writing Documents	Using Language Carefully	Completing a Job Application
Reading Body Language and mixed Messages	Constructive Criticism in Writing	One-on-One Conversations	Writing a Cover Letter
Matching Verbal and Nonverbal communication		Small Group Communication	Things to Include in a Résumé
Improving Nonverbal Indicators		Large Group Communication	Selling Yourself in a Résumé

Nonverbal Feedback		Making Speeches	Terms to Use in a Résumé
Showing Confidence Nonverbally		Involving the Audience	Describing Your Job Strengths
Showing Assertiveness		Answering Questions	Organizing Your Résumé
		Visual and Media Aids	Writing an Electronic Résumé
		Errors in Presentation	Dressing Up Your Résumé

1.2 Demonstrate creativity by asking challenging questions and applying innovative procedures and methods.

Teamwork and Problem Solving	Meeting Etiquette
Thinking Creatively	Preparation and Participation in Meetings
Taking Risks	Conducting Two-Person or Large Group Meetings
Building Team Communication	Inviting and Introducing Speakers
	Facilitating Discussions and Closing
	Preparing Visual Aids
	Virtual Meetings

1.3 Exhibit critical thinking and problem solving skills to locate, analyze and apply information in career planning and employment situations.

Problem Solving	Customer Service	The Application Process	Interviewing Skills	Finding the Right Job
Transferable Job Skills	Gaining Trust and Interacting with Customers	Providing Information, Accuracy and Double Checking	Preparing for an Interview	Locating Jobs and Networking
Becoming a Problem Solver	Learning and Giving Customers What They Want	Online Application Process	Questions to Ask in an Interview	Job Shopping Online
Identifying a Problem	Keeping Customers Coming Back	Following Up After Submitting an Application	Things to Include in a Career Portfolio	Job Search Websites
Becoming a Critical Thinker	Seeing the Customer's Point	Effective Résumés:	Traits Employers are Seeking	Participation in Job Fairs
Managing	Selling Yourself and the Company	Matching Your Talents to a Job	Considerations Before Taking a Job	Searching the Classified Ads
	Handling Customer Complaints	When a Résumé Should be Used		Using Employment Agencies
	Strategies for Customer Service			Landing an Internship
				Staying Motivated to Search

1.4 Model work readiness traits required for success in the workplace including integrity, honesty, accountability, punctuality, time management, and respect for diversity.

Workplace Ethics	Personal Characteristics	Employer Expectations	Business Etiquette	Communicating at Work
Demonstrating Good Work Ethic	Demonstrating a Good Attitude	Behaviors Employers Expect	Language and Behavior	Handling Anger
Behaving Appropriately	Gaining and Showing Respect	Objectionable Behaviors	Keeping Information Confidential	Dealing with Difficult Coworkers
Maintaining Honesty	Demonstrating Responsibility	Establishing Credibility	Avoiding Gossip	Dealing with a Difficult Boss
Playing Fair	Showing Dependability	Demonstrating Your Skills	Appropriate Work Email	Dealing with Difficult Customers
Using Ethical Language	Being Courteous	Building Work Relationships	Cell Phone Etiquette	Dealing with Conflict

Showing Responsibility	Gaining Coworkers' Trust		Appropriate Work Texting	
Reducing Harassment	Persevering		Understanding Copyright	
Respecting Diversity	Handling Criticism		Social Networking	
Making Truthfulness a Habit	Showing Professionalism			
Leaving a Job Ethically				

1.5 Apply the appropriate skill sets to be productive in a changing, technological, diverse workplace to be able to work independently and apply team work skills.

Expected Work Traits	Teamwork	Time Management
Demonstrating Responsibility	Teamwork Skills	Managing Time
Dealing with Information Overload	Reasons Companies Use Teams	Putting First Things First
Transferable Job Skills	Decisions Teams Make	Juggling Many Priorities
Managing Change	Team Responsibilities	Overcoming Procrastination
Adopting a New Technology	Problems That Affect Teams	Organizing Workspace and Tasks
	Expressing Yourself on a Team	Staying Organized
	Giving and Receiving Constructive Criticism	Finding More Time
		Managing Projects
		Prioritizing Personal and Work Life

1.6 Present a professional image through appearance, behavior and language.

On-the-Job Etiquette	Person-to-Person Etiquette	Communication Etiquette	Presenting Yourself
Using Professional Manners	Meeting Business Acquaintances	Creating a Good Impression	Looking Professional
Introducing People	Meeting People for the First Time	Keeping Phone Calls Professional	Dressing for Success
Appropriate Dress	Showing Politeness	Proper Use of Work Email	Showing a Professional Attitude
Business Meal Functions		Proper Use of Cell Phone	Using Good Posture
Behavior at Work Parties		Proper Use in Texting	Presenting Yourself to Associates
Behavior at Conventions			Accepting Criticism
International Etiquette			Demonstrating Leadership
Cross-Cultural Etiquette			
Working in a Cubicle			

Support of CTAE Foundation Course Standards and Georgia Standards of Excellence L9-10RST 1-10 and L9-10WHST 1-10:
Georgia Standards of Excellence ELA/Literacy standards have been written specifically for technical subjects and have been adopted as part of the official standards for all CTAE courses.

Course Standard 2

AFNR-PSB-2

Explore, develop, and implement the comprehensive program of agricultural education, learn and demonstrate safe working habits in the agriculture lab and work sites, demonstrate selected competencies in leadership through the FFA and agricultural industry organizations, and develop plans for a Supervised Agricultural Experience Program (SAEP).

2.1 Explain the role of the Agricultural Education program and the FFA in personal development.
2.2 Demonstrate knowledge learned through a SAEP.
2.3 Develop leadership and personal development skills through participation in the FFA.
2.4 Explore career opportunities in horticulture/plant science through the FFA and Agricultural Education Program.
2.5 Explore the professional agricultural organizations associated with the course content.

Course Standard 3

AFNR-PSB-3

Define and explain the importance of plant science in biotechnology.

3.1 Define science and agriscience.
3.2 Demonstrate the scientific method.
3.3 Explain why agriculture is an applied science.
3.4 Describe at least three advances in agriculture resulting from agricultural research.
3.5 Compile a list of historical events related to agricultural research and development.
3.6 Distinguish between basic and applied research.
3.7 Describe the role of plants in the food chain.
3.8 Describe the role plants play in the environment.
3.9 Explain how plants are used in the food and fiber system and ornamental purposes.
3.10 Trace the origin of common crop and ornamental plants.
3.11 Discuss the economic importance of plant production.
3.12 Demonstrate proper use of the compound and dissecting microscopes.

Course Standard 4

AFNR-PSB-4

Differentiate between plants utilizing scientific plant classification.

4.1 Write scientific names according to set guidelines.
4.2 Distinguish the differences between the levels of the classification system.
4.3 Explain the importance of using a universal classification system.
4.4 Discuss the importance of the plant patent system.
4.5 Define and explain the dichotomous key and use it to identify unknown plants and other items.
4.6 Identify terms used to describe the characteristics of plants.
4.7 Name and describe the major plant types.
4.8 Identify plant species within the major plant types.
4.9 Discuss the differences between vascular and nonvascular plants.

Course Standard 5

AFNR-PSB-5

Identify the parts of plant cells and describe their physiology.

5.1 Identify and describe the components of plant cells.
5.2 List the functions of plant cell components in relation to plant growth.
5.3 Distinguish between plant cells and animal cells.

5.4 Summarize the three kinds of plant cell activity (division, enlargement, and differentiation).
5.5 Describe the life cycle of a plant cell.
5.6 List phases of plant growth.
5.7 Identify the zone of elongation and differentiation.
5.8 Identify ways that osmosis affects plants.
5.9 Describe how water moves into and out of plant cells.
5.10 Define important terms and functions related to plant cells including osmosis, diffusion, etc.

Course Standard 6

AFNR-PSB-6

Explain technological advancements in plant development, reproduction, and protection.

6.1 Trace the development of modern species and varieties.
6.2 Outline a procedure that early plant breeders might have used to domesticate a wild plant species.
6.3 Define biotechnology terms including plant evolution, natural and artificial selection, genetic variation, etc.
6.4 Explain the role of biotechnology and bioengineering in modern plant production.
6.5 Compare traditional plant breeding and genetic engineering of plants.
6.6 Demonstrate plant tissue culture procedures and successfully propagate plant through plant tissue culture.
6.7 Describe the effects of growth hormones on tissue culture success.
6.8 Explain the importance of rhizobia bacteria to legumes.
6.9 Describe the importance of using legumes in agricultural operations.
6.10 Inoculate legumes with rhizobia bacteria.
6.11 Control plant growth through the application of growth inhibitors, stimulants, and cultural practices.
6.12 Identify the major plant hormones that are important to plant growth.
6.13 Explain why forcing of plants is important to the horticulture and related plant industries.
6.14 Discuss and give examples of the importance of genetic variation in the gene pool.
6.15 Debate the use of genetically modified organisms.

Course Standard 7

AFNR-PSB-7

Identify and describe plant nutritional needs.

7.1 Describe the role of nutrients in plant growth and development.
7.2 List primary and secondary plant nutrients.
7.3 Define plant needs for micro nutrients (trace elements).
7.4 Describe the role primary nutrients play in plant growth and development.
7.5 Explain the role of secondary and micro nutrients in plant growth and development.
7.6 Identify natural methods of supplying plants with nutrients.
7.7 Identify and prescribe artificial sources of plant nutrients.
7.8 Describe common symptoms of plants with excess nutrients and prescribe remedies.
7.9 Describe common symptoms of nutrient deficient plants and prescribe remedies.
7.10 Use concepts to solve soluble salt problems in soils.
7.11 Discuss the importance of soil tests and the application of prescribed remedies.
7.12 Conduct soil samples and interpret sample test results.
7.13 Analyze plant tissue sample.

7.14 Describe soil sampling procedures.
7.15 Identify key plant parts involved in nutrient transport.
7.16 Describe the process of nutrient transport.

Course Standard 8

AFNR-PSB-8

Evaluate soil characteristics for production capability.

8.1 Identify functions of soils on plant production.
8.2 Identify acids and bases using the pH scale.
8.3 Describe the importance of soil pH on crops.
8.4 Recommend and describe compounds that will change the soil pH.
8.5 Identify the soil pH best suited for certain crops.
8.6 Describe the composition of an ideal soil.
8.7 List factors that contribute to soil composition.
8.8 Identify various problems with soils that effect plant growth.
8.9 Estimate the amount of organic matter in a soil sample.
8.10 Describe the effect of macro and micro animal and plant products/waste on the soil.
8.11 Discuss the major horizons of mineral soils and identify their characteristics.
8.12 Classify soil horizons by color, texture, or structural composition.
8.13 Identify the soil structural classes.
8.14 Describe the effects of soil structure on crop production.
8.15 Identify the ways humans, animals and machinery can affect soil structure.
8.16 Sort and identify the three major constituents of mineral soil.
8.17 Describe each soil constituent relative to size and other characteristics.
8.18 Describe the effect of soil texture in agricultural operations.
8.19 Identify commonly used artificial soils, listing their advantages and disadvantages.
8.20 Select an artificial soil mixture for specific uses.
8.21 List sources and characteristics of commonly used soil mix ingredients.

Course Standard 9

AFNR-PSB-9

Diagram the life cycles of plants and explain plant reproduction.

9.1 Describe sexual and asexual reproduction in plants.
9.2 Identify the advantages of each type of plant propagation.
9.3 Categorize important agronomic and ornamental plants based on commercial propagation methods.
9.4 Define annual, winter annual, perennial, and biennial.
9.5 Trace the life cycle of plants and phases of growth.
9.6 Identify the male and female parts of flowering plants.
9.7 Describe the functions of each flower part.
9.8 Describe the processes of pollination and fertilization in plants.
9.9 Explain the process by which gametes are produced in both the male and female parts of the flower.
9.10 Distinguish between monoecious and dioecious plants.
9.11 Distinguish between complete and incomplete flowers.
9.12 Define cross-pollination and self-pollination.
9.13 Define fruit set and parthenocarpic fruit.
9.14 Classify the types of fruits and flowers.
9.15 Describe the formation and role fruits play in reproduction.
9.16 Discuss seed dispersal.

9.17 Identify methods of dispersal of common plants.
9.18 Identify factors necessary for seed germination.
9.19 Describe the process of germination.
9.20 Explain the importance of seed dormancy in plant survival.
9.21 Demonstrate scarify and stratify of seeds.
9.22 Describe and apply hypogeal and epigeal germination.

Course Standard 10

AFNR-PSB-10

Explain the importance of genetics in plant breeding.

10.1 Describe Mendel's experiments in plant breeding.
10.2 Describe Law of Independent Assortment.
10.3 Discuss the difference between heterozygous and homozygous.
10.4 List the seven plant characteristics of the garden pea used extensively by Mendel.
10.5 Discuss the two factors that influenced Mendel to use garden peas as his plant variety for studying inheritance of plants.
10.6 Predict genetic outcome using a Punnett Square.
10.7 Describe the structure of a DNA (Deoxyribonucleic acid) molecule.
10.8 Define DNA and RNA (Ribonucleic acid).
10.9 Discuss and list examples of major advances in agronomic production due to heterosis.
10.10 Determine the difference between F1 and F2 generations and describe the use of each in plant breeding.
10.11 Generate crossbred plants through plant breeding.

Course Standard 11

AFNR-PSB-11

Analyze the environmental requirements of plants.

11.1 Differentiate between climatic regions of Georgia and the United States.
11.2 Explain climatic effects on soils and the resulting effect on plant production.
11.3 Determine temperature and the effects of temperature on plant production.
11.4 Convert temperature measurements from Fahrenheit to Celsius and Celsius to Fahrenheit.
11.5 Distinguish between cool season and warm season plants.
11.6 Explain the importance of temperature on germination, pollination, and other plant functions.
11.7 Utilize the plant hardiness zoning classification system for plants.
11.8 Measure precipitation.
11.9 Determine the amount of annual precipitation in the various parts of Georgia, and the United States and describe the limitations of plant production based on rainfall.
11.10 Match plants adapted to regions based on rainfall.
11.11 Measure humidity and explain the importance to agriculture.
11.12 Explain evaporative cooling and limitation.
11.13 Explain the effect of light on plants and agricultural production practices.
11.14 Define photoperiodism and demonstrate the use in plant production.
11.15 Distinguish between light sources, intensity, and quality and prescribe light needs for plants.
11.16 Demonstrate the effects of light colors (chromatography) and intensity on plants.
11.17 Measure wind velocity and explain the effects of wind on plants, structures, etc.
11.18 Determine the best location for orchards, greenhouses, and related essential structures based on climatic conditions.

11.19 Differentiate among the various tropisms including geotropism, phototropism, and chemotropism.
11.20 Explain why plants respond to stimuli and grow in certain directions.

Course Standard 12

AFNR-PSB-12

Explain the uses of plants in medicine, food crops, animal feeds, and ornamental applications.

12.1 Describe how and what plants can be used for medicinal purposes.
12.2 Describe the importance of food crops and identify food crops grown locally.
12.3 Explain the economic impact of food crops.
12.4 List major agronomic foods crops and identify the region of Georgia or the United States where each is grown.
12.5 Define the use and economic importance of ornamental plants.

Course Standard 13

AFNR-PSB-13

Propagate plants using methods of vegetative cloning and sexual reproduction.

13.1 Define cloning and describe the materials and methods of cloning.
13.2 Explain the benefits of cloning plants.
13.3 Prescribe plant propagation procedures based on economics and reproduction success rate.
13.4 Differentiate between sexual and asexual reproduction.
13.5 Select and utilize plant hormones in plant propagation.
13.6 Explain the stimuli and response effect of plant hormones used in plant propagation.
13.7 Propagate plants though sexual and asexual reproduction.

Course Standard 14

AFNR-PSB-14

Identify and classify weeds, prescribe control methods, and describe the economic and environmental effects that weeds have on agricultural production.

14.1 Define and classify weeds according to plant characteristics.
14.2 Identify the economic and aesthetic impact of weeds.
14.3 Explain how weeds compete with plants in fields, greenhouses, landscapes, etc.
14.4 Calculate the economic threshold for weed control measures to be implemented.
14.5 Describe actions, conditions, vectors, and weed characteristics that help in distribution of weed seeds.
14.6 Identify characteristics of weeds that affect treatment type and effectiveness of treatment.
14.7 Identify common weed plants and the crops/locations they infest.
14.8 Prescribe methods of weed control and the appropriate use of weed control measures.
14.9 Explain the importance of Integrated Pest Management (IPM).
14.10 Interpret and implement pesticide label application instructions.
14.11 Debate environmental concerns related to weed control.
14.12 Prescribe alternative methods to chemical weed control.
14.13 Compare and contrast advantages and disadvantages of specific weed control measures.
14.14 Discuss and explain methods of safe herbicide use.
14.15 Demonstrate the proper application method for herbicides.

Course Standard 15

AFNR-PSB-15

Identify, determine control methods, and define the environmental and economic impact insects have on plant production.

15.1 Explain why the study of entomology is important.
15.2 Classify insects using a dichotomous key, and reference materials.
15.3 Describe and identify body parts of insects.
15.4 Identify common agricultural pests by sight and describe the damage done by insects.
15.5 Distinguish between beneficial and harmful insects.
15.6 Describe beneficial insects and the ways in which beneficial insects control pests.
15.7 Identify common beneficial insects by sight and prescribe measures to encourage their continued presence.
15.8 Discuss the importance of insects in relation to pollination.
15.9 Describe chemical and mechanical insect control measures available to producers to protect plants.
15.10 Discuss how natural pest control measures can be utilized by producers to protect plants.
15.11 Compare and contrast the advantages and disadvantages of using insecticides with non-chemical, organic plant production.
15.12 Explain why environmentally safe insect controls are needed.
15.13 Discuss the use of Integrated Pest Management for controlling insects.
15.14 Demonstrate the safe use of pesticides.

Course Standard 16

AFNR-PSB-16

Identify diseases, related organisms, and physiological disorders affecting plants, and prescribe methods of prevention and control.

16.1 Discuss the impact of diseases, nematodes, and physiological disorders on plant production.
16.2 Classify the types of plant diseases and casual organism.
16.3 Prescribe methods of preventing and controlling plant disease, nematodes, and physiological disorders.
16.4 Explain factors necessary for disease infection in plants.
16.5 Diagram the life cycle of common diseases.
16.6 Explain how fungi, bacteria, and viruses are spread.
16.7 Identify common plant diseases by symptoms and signs.
16.8 Define key terms related to plant pathology.
16.9 Trace the history and importance of plant pathology.
16.10 Describe the types of nematodes and how they damage plants.
16.11 Explain how unfavorable environmental conditions can affect disease or disease-like infestations in plants.
16.12 Differentiate between pathogenic and non-pathogenic diseases.
16.13 Demonstrate the safe use of pesticides.

Course Standard 17

AFNR-PSB-17

Analyze the water-plant relationship and describe how water and other materials move through the plant.

17.1 Describe the three categories of water that may be present in the soil.
17.2 Describe hydraulic conductivity, infiltration, and percolation.
17.3 Distinguish between soil texture and bulk density and how they affect soil-water.
17.4 Define absorption and describe how absorption takes place.
17.5 Explain how soil solution enters root hairs.
17.6 Describe and explain the movement of water in plant cells.
17.7 Distinguish between xylem and phloem based on function.

Course Standard 18

AFNR-PSB-18

Evaluate environmentally controlled plant growth systems.

18.1 Discuss why environmentally-controlled structures are used and describe their advantages.
18.2 Determine the use of each of the environmentally-controlled structures based on the plants to be produced.
18.3 Diagram the environmental control components of greenhouses, cold frames, and other plant growth structures.
18.4 Describe how hydroponic systems are used in horticulture and plant science.
18.5 Describe the essential elements of a hydroponic system.

Course Standard 19

AFNR-PSB-19

Analyze the effect of plant production on the environment.

19.1 Explain the importance of plant processes to life on earth.
19.2 Explain the role of plants in the food chain.
19.3 Describe photosynthesis and respiration analyzing the role CO_2 and O_2 play.
19.4 Describe how conventional agricultural practices affect the environment.
19.5 Describe new agricultural practices that are environmentally friendly.
19.6 Compare and contrast the advantages and disadvantages of conventional versus organic farming.
19.7 Explain the importance of compost in the production of plants.
19.8 Describe how composting works and the procedures for creating a compost pile.
19.9 Describe uses for plant by-products and the environmental benefits to using them.
19.10 Define methods of erosion prevention and prescribe erosion control measures for a specific site in the community.

Georgia Department of Education

Agriculture, Food & Natural Resources Career Cluster
Animal Science Technology / Biotechnology
Course Number 02.42100

Course Description

This course is designed to introduce students to the scientific principles that underlie the breeding and husbandry of agricultural animals, and the production, processing, and distribution of agricultural animal products. This course introduces scientific principles applied to the animal industry; covers reproduction, production technology, processing, and distribution of agricultural animal products. Classroom and laboratory activities are supplemented through supervised agricultural experiences and leadership programs and activities.

Course Standard 1

AFNR-ASB-1

The following standard is included in all CTAE courses adopted for the Career Cluster/Pathways. Teachers should incorporate the elements of this standard into lesson plans during the course. The topics listed for each element of the standard may be addressed in differentiated instruction matching the content of each course. These elements may also be addressed with specific lessons from a variety of resources. This content is not to be treated as a unit or separate body of knowledge but rather integrated into class activities as applications of the concept.

Standard: Demonstrate employability skills required by business and industry.

The following elements should be integrated throughout the content of this course.

1.1 Communicate effectively through writing, speaking, listening, reading, and interpersonal abilities.

Person-to-Person Etiquette	Telephone and Email Etiquette	Cell Phone and Internet Etiquette	Communicating At Work	Listening
Interacting with Your Boss	Telephone Conversations	Using Blogs	Improving Communication Skills	Reasons, Benefits, and Barriers
Interacting with Subordinates	Barriers to Phone conversations	Using Social Media	Effective Oral Communication	Listening Strategies
Interacting with Co-workers	Making and Returning Calls		Effective Written Communication	Ways We Filter What We Hear
Interacting with Suppliers	Making Cold Calls		Effective Nonverbal Skills	Developing a Listening Attitude
	Handling Conference Calls		Effective Word Use	Show You Are Listening
	Handling Unsolicited Calls		Giving and Receiving Feedback	Asking Questions
				Obtaining Feedback
				Getting Others to Listen

Nonverbal Communication	Written Communication	Speaking	Applications and Effective Résumés
Communicating Nonverbally	Writing Documents	Using Language Carefully	Completing a Job Application
Reading Body Language and mixed Messages	Constructive Criticism in Writing	One-on-One Conversations	Writing a Cover Letter
Matching Verbal and Nonverbal communication		Small Group Communication	Things to Include in a Résumé
Improving Nonverbal Indicators		Large Group Communication	Selling Yourself in a Résumé

Nonverbal Feedback		Making Speeches	Terms to Use in a Résumé
Showing Confidence Nonverbally		Involving the Audience	Describing Your Job Strengths
Showing Assertiveness		Answering Questions	Organizing Your Résumé
		Visual and Media Aids	Writing an Electronic Résumé
		Errors in Presentation	Dressing Up Your Résumé

1.2 Demonstrate creativity by asking challenging questions and applying innovative procedures and methods.

Teamwork and Problem Solving	Meeting Etiquette
Thinking Creatively	Preparation and Participation in Meetings
Taking Risks	Conducting Two-Person or Large Group Meetings
Building Team Communication	Inviting and Introducing Speakers
	Facilitating Discussions and Closing
	Preparing Visual Aids
	Virtual Meetings

1.3 Exhibit critical thinking and problem solving skills to locate, analyze and apply information in career planning and employment situations.

Problem Solving	Customer Service	The Application Process	Interviewing Skills	Finding the Right Job
Transferable Job Skills	Gaining Trust and Interacting with Customers	Providing Information, Accuracy and Double Checking	Preparing for an Interview	Locating Jobs and Networking
Becoming a Problem Solver	Learning and Giving Customers What They Want	Online Application Process	Questions to Ask in an Interview	Job Shopping Online
Identifying a Problem	Keeping Customers Coming Back	Following Up After Submitting an Application	Things to Include in a Career Portfolio	Job Search Websites
Becoming a Critical Thinker	Seeing the Customer's Point	Effective Résumés:	Traits Employers are Seeking	Participation in Job Fairs
Managing	Selling Yourself and the Company	Matching Your Talents to a Job	Considerations Before Taking a Job	Searching the Classified Ads
	Handling Customer Complaints	When a Résumé Should be Used		Using Employment Agencies
	Strategies for Customer Service			Landing an Internship
				Staying Motivated to Search

1.4 Model work readiness traits required for success in the workplace including integrity, honesty, accountability, punctuality, time management, and respect for diversity.

Workplace Ethics	Personal Characteristics	Employer Expectations	Business Etiquette	Communicating at Work
Demonstrating Good Work Ethic	Demonstrating a Good Attitude	Behaviors Employers Expect	Language and Behavior	Handling Anger
Behaving Appropriately	Gaining and Showing Respect	Objectionable Behaviors	Keeping Information Confidential	Dealing with Difficult Coworkers
Maintaining Honesty	Demonstrating Responsibility	Establishing Credibility	Avoiding Gossip	Dealing with a Difficult Boss
Playing Fair	Showing Dependability	Demonstrating Your Skills	Appropriate Work Email	Dealing with Difficult Customers
Using Ethical Language	Being Courteous	Building Work Relationships	Cell Phone Etiquette	Dealing with Conflict

Showing Responsibility	Gaining Coworkers' Trust		Appropriate Work Texting	
Reducing Harassment	Persevering		Understanding Copyright	
Respecting Diversity	Handling Criticism		Social Networking	
Making Truthfulness a Habit	Showing Professionalism			
Leaving a Job Ethically				

1.5 Apply the appropriate skill sets to be productive in a changing, technological, diverse workplace to be able to work independently and apply team work skills.

Expected Work Traits	Teamwork	Time Management
Demonstrating Responsibility	Teamwork Skills	Managing Time
Dealing with Information Overload	Reasons Companies Use Teams	Putting First Things First
Transferable Job Skills	Decisions Teams Make	Juggling Many Priorities
Managing Change	Team Responsibilities	Overcoming Procrastination
Adopting a New Technology	Problems That Affect Teams	Organizing Workspace and Tasks
	Expressing Yourself on a Team	Staying Organized
	Giving and Receiving Constructive Criticism	Finding More Time
		Managing Projects
		Prioritizing Personal and Work Life

1.6 Present a professional image through appearance, behavior and language.

On-the-Job Etiquette	Person-to-Person Etiquette	Communication Etiquette	Presenting Yourself
Using Professional Manners	Meeting Business Acquaintances	Creating a Good Impression	Looking Professional
Introducing People	Meeting People for the First Time	Keeping Phone Calls Professional	Dressing for Success
Appropriate Dress	Showing Politeness	Proper Use of Work Email	Showing a Professional Attitude
Business Meal Functions		Proper Use of Cell Phone	Using Good Posture
Behavior at Work Parties		Proper Use in Texting	Presenting Yourself to Associates
Behavior at Conventions			Accepting Criticism
International Etiquette			Demonstrating Leadership
Cross-Cultural Etiquette			
Working in a Cubicle			

Support of CTAE Foundation Course Standards and Georgia Standards of Excellence L9-10RST 1-10 and L9-10WHST 1-10:

Georgia Standards of Excellence ELA/Literacy standards have been written specifically for technical subjects and have been adopted as part of the official standards for all CTAE courses.

Course Standard 2

AFNR-ASB-2

Orient and apply the comprehensive program of agricultural education, learns to work safely in the agriculture lab and work sites, demonstrates selected competencies in leadership through the FFA and agricultural industry organizations, and develops plans for a Supervised Agricultural Experience Program (SAEP).

2.1 Explain the role of the Agriculture Education program and the FFA in personal development.
2.2 Demonstrate knowledge learned through a SAEP.
2.3 Develop leadership and personal development skills through participation in the FFA.
2.4 Explore career opportunities in animal science though the FFA and Agriculture Education Program.
2.5 Explore the professional agricultural organizations associated with the course content.

Course Standard 3

AFNR-ASB-3

Demonstrate the application of scientific methods in agricultural animal research and production.

3.1 Distinguish between basic and applied science.
3.2 Discuss the advances made in American agriculture.
3.3 Analyze how agricultural research has benefited the consumer.
3.4 Cite scientific discoveries in animal agriculture.
3.5 Explain scientific developments that have revolutionized animal agriculture.
3.6 List pharmaceuticals that are derived from animals and list their uses.
3.7 Discuss agriculture as a science.
3.8 Perform the steps involved in the scientific method.
3.9 Conduct a simple scientific research study.
3.10 Investigate and reports on selected animal science technology/biotechnology careers.

Course Standard 4

AFNR-ASB-4

Describe the various phases, segments, trends, consumption, and economic scope of the large animal industry.

4.1 Describe ecological balance.
4.2 Describe the various segments of the beef industry.
4.3 Research the various phases of the sheep industry and the importance of wool as a consumer fabric.
4.4 Assess the various phases of the swine industry.
4.5 Explain how horses are used historically and in modern times.
4.6 Develop a chart of the per capita consumption of products from large animals grown in the United States.
4.7 Justify the use of agricultural land to produce meat animals.
4.8 Identify key production areas of beef cattle and hogs.
4.9 Determine relationships between feed crop production and the production of meat animals.
4.10 Identify breeds of large animals.
4.11 Locate on a map the states and regions foremost in the production of meat animals.

Course Standard 5

AFNR-ASB–5

Describe the various phases, segments, trends, consumption, and economic scope of the poultry industry.

5.1 Summarize the poultry industry's growth trends.
5.2 Evaluate the production of poultry products in each state.
5.3 Identify on a map the states and regions foremost in production of poultry.
5.4 Compute the per capita consumption of chicken, turkey and eggs.
5.5 Describe vertical integration using segments of the poultry industry as examples.
5.6 Outline the operation of modern poultry operations.
5.7 Explain the operation of modern hatcheries.
5.8 Identify breeds of poultry.
5.9 Outline a modern poultry production operation.
5.10 Describe the process of egg development in poultry.
5.11 Trace the biological processes involved in the production of eggs.
5.12 Analyze egg composition.
5.13 Describe chick embryo development.
5.14 Discuss proper storage conditions of hatching eggs.

Course Standard 6

AFNR-ASB-6

Describe the various phases, segments, trends, consumption and economic scope of the dairy industry.

6.1 Identify the major areas and characteristics of dairy production in the United States and compares dairy production among the states.
6.2 Discuss breeds of dairy cows and their characteristics.
6.3 Demonstrate the steps used to milk cows in the modern dairy.
6.4 Determine the per capita consumption of various dairy products.
6.5 Assess the uses of milk from species other than cows and their importance in the dairy industry.
6.6 Identify dairy products, their use and their economic importance.
6.7 Examine the scientific process by which milk is produced.
6.8 Trace the hormonal activity that controls lactation.
6.9 Review the equipment and procedures involved in milking.
6.10 Identify the breeds of dairy cattle.
6.11 Contrast the breeds of dairy cattle, including their origin and breed characteristics.
6.12 Assess the uses of goat and sheep milk in cheese manufacturing.
6.13 Describe the nutritive content of milk.
6.14 Explore the scientific processes of pasteurization and homogenization in milk processing.
6.15 Recognize and explains the differences in milk classifying and grading.
6.16 Demonstrate the conversion of milk to butter, cheese and ice cream products.

Course Standard 7

AFNR-ASB-7

Evaluate trends in the aquaculture industry and the scientific principles involved in the production of aquatic animals.

7.1 Explore the scope of the aquaculture industry.
7.2 Classify the characteristics of ectothermic animals.
7.3 Evaluate the feed-conversion efficiency of fish.

7.4 Research types of aquatic animal production in the United States.
7.5 Investigate the physical characteristics of water and its relationship to fish production.
7.6 Estimate fish populations in production operations by scientific sampling.
7.7 Measure and adjusts water pH as it relates to fish growth and development.
7.8 Describe how fish attain oxygen.
7.9 Explain how oxygen is dissolved into and depleted from water.
7.10 Test pond and river and other water for dissolved oxygen levels.
7.11 Provide for the addition of oxygen to water by mechanical agitation.
7.12 Describe the methods and facilities used in the production of various aquatic animals.
7.13 Interpret the behavioral characteristics of bullfrogs and alligators that make them difficult to produce in confinement.

Course Standard 8

AFNR-ASB-8

Describe the various phases, segments, trends, demand, consumption and economic scope of the alternative and laboratory animals.

8.1 Analyze the advantages and disadvantages of raising alternative agricultural animals.
8.2 Describe alternative animal agriculture industry.
8.3 Explain the potential of ostriches, goats and other alternative animals as food animals.
8.4 Describe the production of certified laboratory animal.
8.5 List the animals most often used in scientific research and explains reasons for their selection and use.
8.6 List the distinguishing characteristics of insects used in agricultural animal production.
8.7 Explain the importance of the honeybee to agriculture and the society of the honeybee.
8.8 Discuss the threat to American agriculture by the Africanized honeybee and explains the biological reasons for the problem.
8.9 Outline production practices to produce organic and natural animal products.

Course Standard 9

AFNR-ASB-9

Classify animals using scientific binomial nomenclature as well as classifies agriculture animals by breed and use.

9.1 Explain how agricultural animals are classified scientifically.
9.2 Explain the use of the binomial system of classification.
9.3 Utilize kingdoms to classify all living organisms.
9.4 Identify characteristics of animals that place them in different classifications.
9.5 Explain how breeds of livestock were developed.
9.6 Explain the purpose of breed associations.
9.7 Classify agricultural animals.
9.8 Identify characteristics that can be used to group objects.
9.9 Categorize common and distinguishing characteristics of several agricultural animals.

Course Standard 10

AFNR-ASB-10

Explain and addresses the general public's food safety and environmental concerns.

10.1 Rationalize consumer's concerns for food safety.
10.2 Explain the causes and types of problems with meat processing and consumption.
10.3 Demonstrate knowledge of how safety problems can be solved.
10.4 Differentiate between meat grading and meat inspection.

10.5 Discuss examples of how genetic engineering has benefited the producer and consumer as well as the concerns over genetic engineering.
10.6 Evaluate producers of agricultural animals as caretakers of the environment.
10.7 Describe the concept of the greenhouse effect.
10.8 Summarize how the balance of oxygen and carbon dioxide is maintained in the atmosphere.
10.9 Discuss how bacteria can be beneficial to the environment.
10.10 Determine consumer concerns with various phases of the animal and meat industry.
10.11 Explain the growth and popularity in organically produced animal products.

Course Standard 11

AFNR-ASB-11

Compare and contrast crucial animal welfare issues and explain the benefits of treating animals in a humane manner and providing for the needs of animals.

11.1 Discern the difference between animal welfare and animal rights.
11.2 Research potential problems brought about by animals being raised in confinement.
11.3 Interpret the reasons given by some people for their objections to raising farm animals.
11.4 Debate the use of production practices such as confinement operations.
11.5 Debate management practices used in the production of agricultural animals.
11.6 Investigate the benefit to producers of content and healthy animals.
11.7 Explain potential problems of animal production such as the continuous use of antibiotics.
11.8 Cite examples of how the use of animals in research has benefited humans.
11.9 Investigate the laws that govern the use of laboratory animals for research.
11.10 Interpret the laws governing the use of agricultural animals.
11.11 Discuss the production and increasing popularity of natural and organic produced animal products.

Course Standard 12

AFNR-ASB-12

Observe and interpret the natural behavior of agricultural animals and relate these behaviors to production practices yielding more content, healthier, and productive animals.

12.1 Describe the importance of ethology in the production of agricultural animals.
12.2 Differentiate between instinctive and learned behaviors of animals.
12.3 Judge animal intelligence based on behavior.
12.4 Describe the conditioning response and its use in animal production.
12.5 Explain how animal behaviors are developed.
12.6 Infer how unusual stimuli and surroundings affect animals.
12.7 Examine how cattle view their surroundings and how that behavior is used to design cattle facilities.
12.8 Describe and identifies social, dominate, flight, and protective behaviors in animals.
12.9 Investigate the social behaviors of agricultural animals.
12.10 Identify dominant animals in a group.
12.11 Discuss how dominant behavior contributes to natural selection.
12.12 Analyze the types of sexual and reproductive behaviors in agricultural animals.
12.13 Observe animal behavior and successfully collect data for an ethogram.
12.14 Describe the methods used by agricultural animals to communicate.
12.15 Describe the types of ingestive behaviors in agricultural animals.
12.16 Explain how the natural behaviors of agricultural animals can be used to provide the animals with a safer, more comfortable environment.

Course Standard 13

AFNR-ASB-13

Apply genetic principles to animal selection, breeding, and production.

13.1 Explain the basic function of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).
13.2 Explain how traits are passed from parent to offspring through genetic transfer.
13.3 Research and explain the concept of dominant genes verses recessive genes.
13.4 Describe the concept of co-dominant genes.
13.5 Explain how producers use the genetic principles to produce desired types of animals.
13.6 Explain how the sex of an animal is determined.
13.7 Explain the difference between phenotypic and genotypic characteristics.
13.8 Compute mathematically the expected color of offspring.
13.9 Compare the expected coat color with results obtained through scientific observation.
13.10 Describe how the concept of heritability is used in the selection of livestock.
13.11 Predict phenotypic and genotypic characteristics in animals.
13.12 Utilize performance data in the selection of livestock.
13.13 Describe Expected Progeny Difference (EPD).

Course Standard 14

AFNR-ASB-14

Apply scientific methods of animal selection and explain the advantages and disadvantages.

14.1 Explain the concept of natural selection.
14.2 Discuss how humans have influenced the development of animals.
14.3 Illustrate how scientific research has influenced the development of animals.
14.4 Cite examples of how problems have developed in animals because of the selection process controlled by humans.
14.5 Compare and contrast the benefits of scientific animal selection and breeding by the producer with natural selection and random mating.
14.6 Trace the stages in the development of modern swine.
14.7 Discuss problems associated with overly muscled pigs.
14.8 Interpret the reasoning behind the selection of sex character in agricultural animals.
14.9 Outline selection criteria for specific agricultural animals and uses.
14.10 Outline the physical characteristics associated with growth in animals.
14.11 Compare and contrast the characteristics of modern beef, swine, and dairy animals with those of their ancestors.
14.12 Cite examples of heterosis in agricultural animal production.

Course Standard 15

AFNR-ASB-15

Discuss the reproductive anatomy and biological processes involved in the reproduction of agricultural animals.

15.1 Distinguish between asexual and sexual reproduction.
15.2 Explain the process by which gametes are produced in both the male and female.
15.3 Diagram and explain the steps involved in meiosis.
15.4 Describe the parts and functions of the male and female reproductive system.
15.5 Analyze the functions of the hormones that control reproduction.
15.6 Describe the phases of the female reproductive cycle.
15.7 Explain the process by which fertilization takes place.
15.8 Compare the size and shape of sperm cells and egg cells.
15.9 Demonstrate the procedures used in artificial insemination.
15.10 Explain the use and procedures of embryo transfer and evaluate its economic importance.

15.11 Describe the process and advantages of estrus synchronization.
15.12 Research and predict new scientific technology that will be of benefit to livestock producers.

Course Standard 16

AFNR-ASB-16
Describe the physiological processes involved in prenatal and postnatal growth and development of agricultural animals.

16.1 Measure the growth process in an animal.
16.2 Analyze the circumstances of growth that affect production enterprises.
16.3 Distinguish between prenatal and postnatal growth and illustrate the phases of each.
16.4 Describe and explain the phases of mitosis.
16.5 Explain the layers of the blastula and the organs that are derived from each layer.
16.6 Describe the functions of the placenta.
16.7 Identify characteristics of twenty-four, forty-eight, and seventy-two hour old chick embryos.
16.8 Differentiate between body cells and explain the functions of each type cell.
16.9 Sequence fat deposition in an animal's body.
16.10 Investigate and explain why selection for muscling in animals is important.
16.11 Compare and contrast the growth and reproductive phases in an animal's life.
16.12 Describe the effects of hormones in the growth process.
16.13 Describe the effects castration has on the growth of an animal.
16.14 Explain the aging process in animals.
16.15 Distinguish between chronological and physiological age.

Course Standard 17

AFNR-ASB-17
Explain nutrient sources and functions as they relate to monogastric and ruminant agricultural animals.

17.1 List nutrients that are essential to the growth and development of animals.
17.2 Describe the role water plays in supporting animal growth and development.
17.3 Discuss the relationship between proteins and amino acids.
17.4 Identify protein feed sources.
17.5 Distinguish between carnivores, omnivores, and herbivores and give examples.
17.6 Explain the role and importance of protein, carbohydrates, and fats in the diets of animals.
17.7 Identify types of common sugars and their role in animal nutrition.
17.8 Identify the common grains that are used as a source of carbohydrates.
17.9 Distinguish between concentrates and roughages and gives examples of each.
17.10 List the sources of fats, minerals, vitamins, roughages, starches, sugars, proteins, etc., in animal rations.
17.11 Discuss the role that minerals play in animal growth and development.
17.12 Demonstrate the use of chemical tests to indicate the presence of nutrients.
17.13 Distinguish between a monogastric and a ruminant digestive system.
17.14 List and define the function of the organs of monogastric and ruminant digestive systems.
17.15 Explain the differences in feed used by monogastrics and feed used by ruminants.
17.16 Classify agricultural animals as monogastrics or ruminants and predict feed sources of each.

Course Standard 18

AFNR-ASB-18
Investigate the physiological and chemical properties of meat products and preservation.

18.1 Describe the physiological processes that take place in the animal's body at death.
18.2 Explain the steps in the slaughter of meat animals.

18.3 Describe the biological process of ossification.
18.4 Estimate the marbling of beef.
18.5 Explain the value of high verses low yield grades.
18.6 Calculate the quality and yield grades for beef.
18.7 Identify the wholesale and retail cuts of beef, pork, and lamb.
18.8 Explain the different types of tissues that compose muscles.
18.9 Describe the factors that affect the palatability of meats and the sensation of taste.
18.10 Describe the importance of meat to the human diet.
18.11 Evaluate the value of nutrients provided by meat.
18.12 Discuss the types of microbes that cause spoilage of meat products.
18.13 List the factors that favor the growth of microbes.
18.14 Research the scientific principles involved in meat preservation.
18.15 Demonstrate the preservation of meat products using various curing methods.

Course Standard 19

AFNR-ASB-19

Describe the effects, development, and control of parasites in agricultural animals.

19.1 Explain symbiotic relationships.
19.2 Distinguish between mutualism, commensalism, and parasitism.
19.3 Discuss how parasitism causes harm to the host animal.
19.4 Identify parasites of agricultural animals and match the parasite to the host.
19.5 Estimate production losses due to parasites of agricultural animals.
19.6 Diagram the phases of a parasite's life cycle and identify how knowledge of life cycle can be used to control the parasite.
19.7 Differentiate between internal and external parasites.
19.8 Explain how scientific research is used in the control and/or eradication of parasites.
19.9 Explain the conventional means of controlling parasites of agricultural animals.

Course Standard 20

AFNR-ASB-20

Identify and describe animal diseases, animal immune systems, and disease prevention and control programs.

20.1 List the types and characteristics of disease-causing organisms.
20.2 Describe three types and characteristics of bacteria.
20.3 Characterize viruses and protozoa.
20.4 Identify signs and symptoms that are used to recognize and quarantine sick animals.
20.5 List and discuss agricultural animal diseases caused by microorganisms.
20.6 Determine sources of disease-causing organisms in the environment.
20.7 Describe how an animal's immune system works.
20.8 Explain the function of red and white blood cells.
20.9 Describe how disease vaccines are developed and the success of their uses.
20.10 Discuss how antigens enter the body and explain the body's reactions.
20.11 Distinguish between active and passive immunity.
20.12 Differentiate between naturally acquired immunity and artificially acquired immunity.
20.13 Differentiate between infectious and noninfectious diseases.
20.14 Describe how diseases are spread and prescribe methods to limit infection.
20.15 List examples of diseases caused by genetic disorders.
20.16 Cite examples of diseases caused by improper nutrition.
20.17 Research plants that are poisonous to agricultural animals.
20.18 Provide examples of government disease-eradication programs.
20.19 List zoonotic diseases and concerns for human health.