Journal of Agricultural Education, 63(3), 100-116
https://doi.org/10.5032/jae.2022.03100

Technical Agriculture Skills Teachers Need to Teach Courses in the Plant Systems Pathway

Jay K. Solomonson[1], Trent Wells[2], Mark S. Hainline[3], Bryan D. Rank[4], Matthew Wilson[5], Skyler P. Rinker[6], and Steven "Boot" Chumbley[7]

Abstract

Agricultural teacher education programs are designed to prepare competent teachers who are ready to teach students in public schools. One aspect of agricultural teacher education is ensuring teachers are ready to lead instruction in various aspects of school-based agricultural education (SBAE), such as teaching students various technical agriculture skills. As part of a larger study, we used a three-round Delphi study to identify the technical agriculture skills SBAE teachers in Illinois and Iowa need to effectively teach courses in the Plant Systems pathway within the broader Agriculture, Food, and Natural Resources (AFNR) Career Cluster. A panel of 27 experienced SBAE teachers nominated by their colleagues contributed data for our study. Eighteen teachers participated in all three rounds. At the conclusion of our Delphi study, we identified 82 technical agriculture skills. To help ensure teachers are competent and prepared to teach courses in the Plant Systems pathway, we suggest several approaches agricultural teacher educators should consider: (1) facilitating opportunities to implement technical agriculture skill development opportunities within agricultural teacher education programs, (2) engaging with agricultural faculty who teach technical agriculture courses to pre-service teachers, and (3) using our list of 82 skills as a springboard to facilitate future scholarly inquiry on the topic. While our results are not generalizable beyond the SBAE teachers in Illinois and Iowa, we do believe our findings are valuable to SBAE stakeholders. To enhance generalizability and provide a more thorough exploration of teachers' technical agriculture skill needs, replication of our study should occur in other states.

Keywords: technical agriculture; skills; plant

Author Note: This paper is a product of the Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa. Project No. IOWO3813 and sponsored by Hatch Act and State of Iowa funds.
Correspondence concerning this article should be addressed to Jay K. Solomonson, Department of Agriculture, Illinois State University, Campus Box 5020, Normal, IL 61790-5020.
Email: jksolom@ilstu.edu

[1] Jay K. Solomonson is an Assistant Professor of Agricultural Education in the Department of Agriculture at Illinois State University, 140 Ropp Ag Building, Normal, IL 61790, jksolom@ilstu.edu
[2] Trent Wells is an Assistant Professor of Agricultural Education in the Department of Agriculture at Southern Arkansas University, 100 E. University, Magnolia, AR 71753, ktwells@saumag.edu
[3] Mark S. Hainline is an Assistant Professor of Agricultural Education in the School of Agricultural Sciences at Sam Houston State University, 440L Fred Pirkle Engineering Technology Center, Huntsville, TX 77341, msh004@shsu.edu
[4] Bryan D. Rank is an Assistant Professor of Agricultural Education in the Department of Agriculture at Arkansas Tech University, Dean Hall, Room 123E, Russellville, AR 72801, brank@atu.edu
[5] Matthew Wilson is an Assistant Professor of Horticulture in the Department of Agriculture at Arkansas Tech University, Dean Hall, Room 123A, Russellville, AR 72801, mwilson58@atu.edu
[6] Skyler P. Rinker is an Assistant Teaching Professor in the Department of Agricultural Education and Studies at Iowa State University, 513 Farm House Lane, Ames, IA 50011, srinker@iastate.edu
[7] Steven "Boot" Chumbley is an Associate Professor of Agricultural Education in the Department of Agriculture, Agribusiness, and Environmental Sciences at Texas A&M University-Kingsville, 700 University Blvd., Kingsville, TX 78363, steven.chumbley@tamuk.edu

Introduction

School-based agricultural education (SBAE) programs are found within schools of differing sizes, community types, and demographics. Philosophically, SBAE programs are intended to reflect the needs of their respective local communities and serve various functions, such as facilitating opportunities for student growth via leadership activities (Phipps et al., 2008), addressing workforce development needs (Wells & Hainline, 2021; Wells et al., 2021), and preparing students for future opportunities in the agricultural industry (Stripling & Ricketts, 2016). To maximize potential for positive student and community impacts, SBAE programs must be led by effective SBAE teachers (Eck et al., 2019). Effective SBAE teachers possess a range of characteristics, such as knowledge about teaching and learning processes and agricultural subject matter knowledge (Eck et al., 2019). Agricultural subject matter knowledge has consistently been identified as characteristic of effective SBAE teachers (Eck et al., 2019; Roberts & Dyer, 2004).

Agricultural subject matter is broad and encompasses a wide range of topic areas commonly taught in SBAE programs, including agribusiness, agricultural mechanics, environmental and natural resources, animal science, and plant science (Phipps et al., 2008). Within the context of agricultural teacher education programs, technical agriculture coursework addressing the different segments of agriculture is typically a significant portion of an undergraduate degree program (Whittington, 2005). The agricultural industry perpetually alters course to meet the needs and desires of modern society (Doerfert, 2011). Likewise, the agricultural subject matter knowledge needs of SBAE teachers change as well. Viewed holistically, the scope of agricultural subject matter knowledge needed by SBAE teachers alongside the progressive nature of the agricultural industry can present challenges for SBAE and its stakeholders, particularly from the perspective of ensuring teachers are competent and prepared to adequately address the purposes of SBAE programs.

To better serve the needs of SBAE stakeholders, there has been a concerted effort to refine SBAE coursework and content standards at the national level. In 2015, The National Council for Agricultural Education presented a revised list of the Agriculture, Food, and Natural Resources (AFNR) Career Cluster Content Standards. These revised standards were detailed across eight career pathways: (1) Agribusiness Systems, (2) Animal Systems, (3) Biotechnology Systems, (4) Environmental Service Systems, (5) Food Products and Processing, (6) Natural Resource Systems, (7) Plant Systems, and (8) Power, Structural, and Technical Systems. Designed to build upon efforts initiated by the United States Department of Education in the early 2000s, the content standards addressed within each pathway were intended to promote student success and align with the agricultural workforce development needs of the 21st century. The pathways and their aligned content standards were intended to be used by SBAE teachers and leaders throughout the United States to inform the progression of SBAE programs (The Council, 2015). These efforts have consequences for agricultural teacher education programs and other SBAE stakeholders, particularly in the context of ensuring teachers are competent, prepared, and effective.

Teacher competence is vital to facilitating and supporting the intended outcomes of SBAE programs (Wells & Hainline, 2021). Ensuring SBAE teachers are both competent in their agricultural subject matter knowledge and prepared to lead instruction in technical agriculture skills has implications beyond impacts on students, the SBAE program, the school, and the community at-large. Teacher competence (or the lack thereof) can not only hinder the learning experience for students but can also create other issues, such as teacher liability concerns (Hainline et al., 2019). Liability concerns relevant to SBAE teachers consist of a spectrum of topics, including student supervision, student safety, and classroom management (Hainline et al., 2019), all of which can be present when providing technical agriculture skill instruction commonly found in SBAE curricula. Moreover, as much of SBAE instruction is laboratory-based (Phipps et al., 2008) and SBAE laboratories are frequently used to support the purposes of SBAE programs (Shoulders & Myers, 2012), SBAE teachers are tasked with creating and managing safe learning environments (Saucier et al., 2014). Doing so requires SBAE teachers be competent in their technical agriculture knowledge and skills (Wells & Hainline, 2021).

By the nature of their profession, teachers must make good judgments and ensure their students are safe (McDaniel, 2020). Zirkle (2017) indicated teachers must perform their duties competently and they must proactively ensure the spaces in which they teach are suitable for instruction to occur. Moreover, Love (2013) noted that the potential for teachers to encounter liability issues can be heightened if teachers are not appropriately prepared for their subject matter area. Love (2013) further indicated many issues related to teacher liability can be addressed through proactive means, such as ensuring teachers are competent and well-prepared to work in their teaching and learning environments.

Beyond addressing teacher liability concerns through adequate teacher preparation, research indicates that sufficient teacher preparation and training, purposeful professional development, possessing adequate self-efficacy, and increased experiences in the classroom can all contribute to increased teacher retention (Solomonson et al., 2018). When specifically examining SBAE, Solomonson et al. (2018) identified a teacher's *Lack of Confidence to Teach the Curriculum* as the top affective factor impacting a SBAE teacher's decision to leave the teaching profession. Findings in similar studies suggest teachers are less likely to leave the profession when they are adequately prepared for their career (Darling-Hammond, 2003; Darling-Hammond et al., 2002). Further, sufficient training and professional development programs have also shown to have a positive impact on retaining teachers (Haynes, 2014; Ingersoll & Smith, 2003). Perhaps if teachers perceived that they were more prepared to teach agricultural subject matter and believed themselves to be competent and prepared to teach their curricula, they might be less likely to exit the profession (Solomonson et al., 2018). In conjunction with teacher liability concerns, this might be useful when also considering teacher attrition issues, which has been identified as a top priority of agricultural teacher education (Foster et al., 2020).

In the context of preparing competent SBAE teachers, recent literature (i.e., Hainline & Wells, 2019; Swafford & Hagler, 2018; Wells & Hainline, 2021; Wells et al., 2021) has focused more extensively and deeply on agricultural mechanics versus other agricultural subject matter areas, such as agribusiness, animal science, and plant science. Albritton and Roberts (2020) explored the technical agriculture skill needs of beginning teachers and addressed a broad swath of agricultural subject matter areas. However, their study was intended primarily to serve the interests of preparing early-career teachers and thus serves as a limitation when considering the technical agriculture skills needed by teachers of all experience levels.

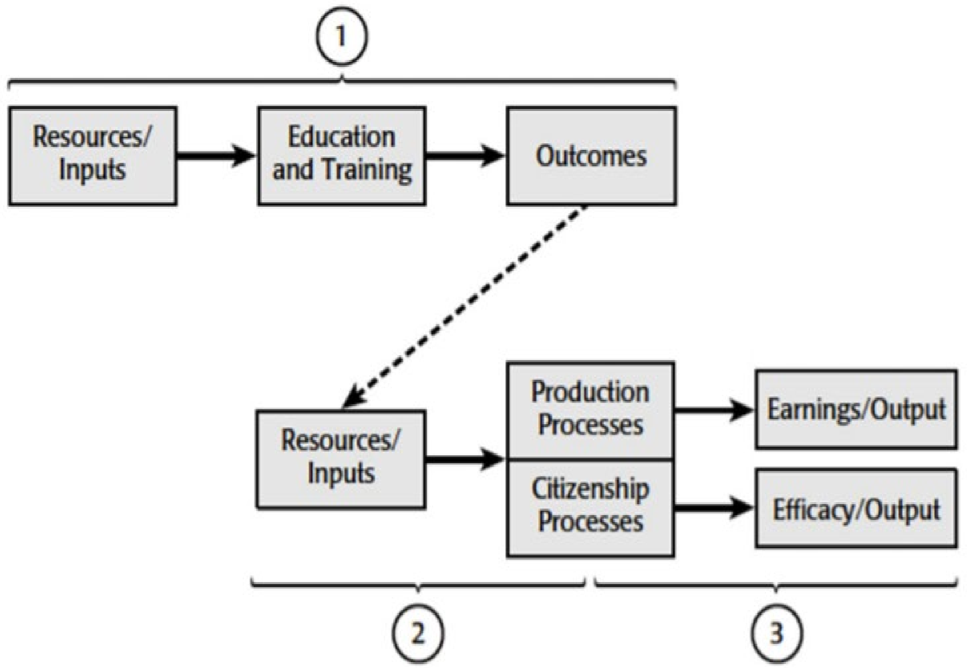
While other scholars such as Clemons et al. (2018), Figland et al. (2019), and Smalley et al. (2019) have recently explored SBAE teachers' professional development needs related to their teaching responsibilities (including agricultural subject matter), limited deeper knowledge about detailed agricultural subject matter items (i.e., specific, identifiable technical agriculture skills within broader agricultural subject matter areas) serves as a limitation to such efforts, thus creating a gap in the literature. As part of a larger effort to address teachers' technical agriculture skills needs, our study focused specifically on the Plant Systems pathway. Our intention was to help fill the existing gap in the literature by providing a list of specific technical agriculture skills that could be used to better inform SBAE stakeholders who have a role in developing competent, prepared teachers, such as agricultural teacher educators and other agricultural faculty at-large, regarding expectations for teacher competence in SBAE programs.

Theoretical Framework

We used human capital theory (HCT) as modeled by Swanson and Holton (2001) to underpin our study (see Figure 1).

Figure 1

A Model of Human Capital Theory



From *Foundations of Human Resource Development* (p. 110), by R. A. Swanson and E. F. Holton, III, 2001, Berrett-Koehler Publishers, Inc. Copyright 2001 by Berrett-Koehler Publishers, Inc. Reprinted with permission.

Human capital encompasses the health and education of people, the stock of educated people and is measured by assessing the quantity and quality of formal education received by individuals (Lutz & KC, 2011). Education consistently emerges as the prime human capital investment for empirical analysis (Sweetland, 1996) and has served as the foundational human capital component of many studies which have evaluated the skills, needs, and education required of individuals as they relate to workforce preparedness (Easterly & Myers, 2017; Hendrix & Morrison, 2018; Robinson & Baker, 2013; Robinson & Garton, 2008; Wells & Hainline, 2021). In the HCT model, Swanson and Holton (2001) describe three key relationships that occur through the process of human capital development. Our study used the first two relationships of their model as a foundation. The first relationship within the HCT model relates to the outcomes of the resources, inputs, education, and training of individuals. These outcomes are then utilized as inputs as the individual progresses to employment and applies the education and training to their work. As noted by Swanson and Holton (2001), as individuals apply their educational outcomes as inputs in the workplace, productivity for the firm which they are employed will be bolstered.

Baye and Prince (2014) add to the conversation related to the application of an individual's education outputs transferring to become inputs to their area of employment by describing human capital as a specialized investment firms are required to make. This definition implies that firms or companies are willing to invest in their employees to help them attain specific knowledge or skills related to their job, thus improving human capital as a resource. When looking at the connection between relationships one and two in the HCT model, knowledge and skills learned from an employee's education should directly transfer as inputs for a firm (production process) as a benefit. Employees are able to contribute relevant knowledge, education, and skills to the firm in which they are employed. In turn, firms can reduce the amount of direct investment they make into human capital through reliance on employees bringing prior knowledge, education, and skills with them to their current employer. This subsequently creates an economic benefit for both employee and employer through an exchange of benefits and cost savings.

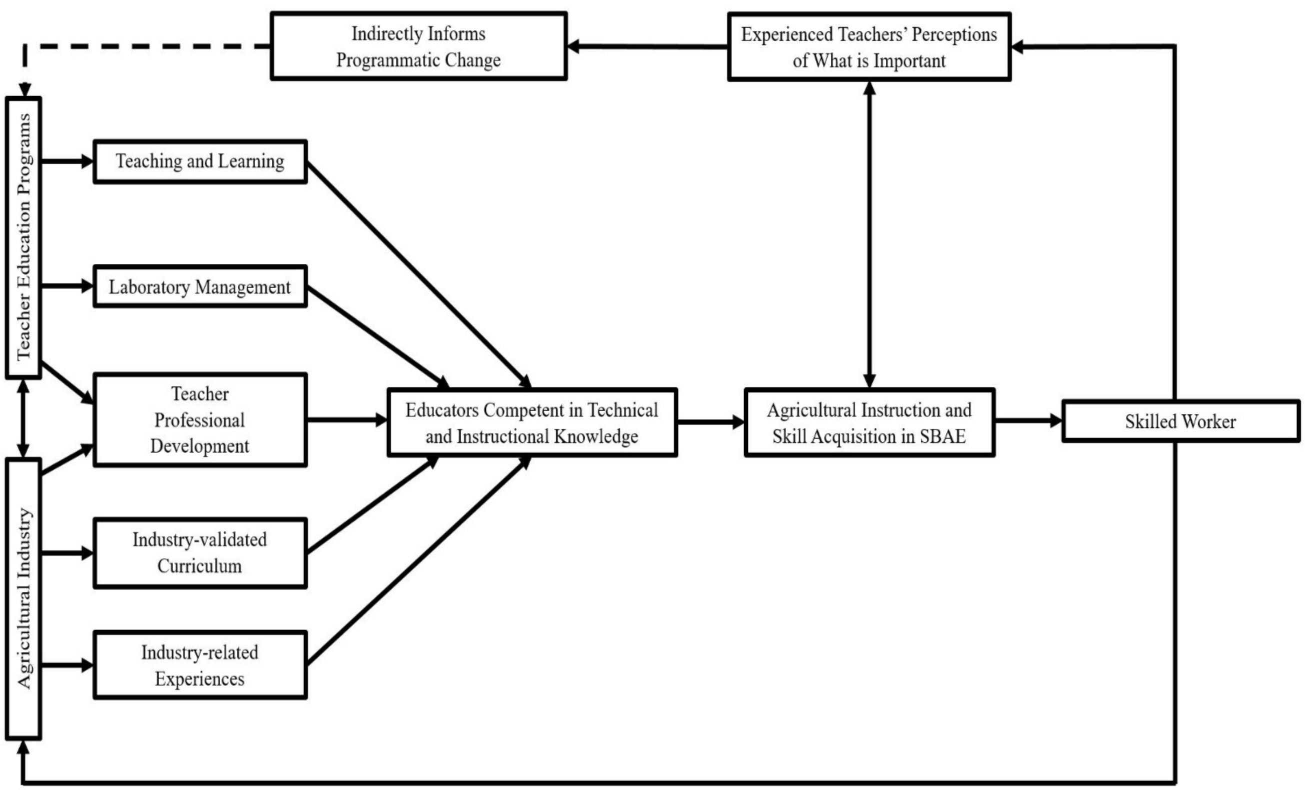
An employee's ability to provide knowledge, skills, and education to their employment stems from the education received in relationship one of the HCT model (i.e., resources, inputs, education, and training of individuals). SBAE teachers who are competent and proficient in relevant agricultural subject matter will not only have a positive impact on increasing the knowledge and skillsets of their students but will contribute to crafting a connection between relationships one and two as employers invest in their employees, as outlined by Swanson and Holton (2001).

Conceptual Framework

We conceptually framed our study using the Agricultural Teacher Education and Agricultural Industry Partnership Model (see Figure 2) presented by Wells et al. (2021).

Figure 2

The Agricultural Teacher Education and Agricultural Industry Partnership Model



From "A Regional Study of the Agricultural Mechanics Knowledge and Skills Needed by School-based Agricultural Education Teachers," by T. Wells, M. S. Hainline, B. D. Rank, K. W. Sanders, and S. B. Chumbley, 2021, *Journal of Agricultural Education, 62*(2), p. 162 (https://doi.org/10.5032/jae.2021.02148). Copyright 2021 by the *Journal of Agricultural Education*. Reprinted with permission.

In particular, we focused on the *Experienced Teachers' Perceptions of What is Important* component of their model. Building upon Roberts and Ball's (2009) Content-based Model for Teaching

Agriculture, Wells et al.'s (2021) model included additional factors contributing toward both the technical agriculture expertise of SBAE teachers and instructional practices and skill learning within SBAE programs (e.g., *Teacher Professional Development*, *Teacher Education Programs*, etc.). Wells et al. (2021) indicated experienced teachers can serve as thought-leaders within their respective programs, communities, and states and can thereby help influence the development of competent, prepared SBAE teachers. Thus, soliciting experienced teachers' perceptions is a fundamental component of facilitating positive changes in SBAE.

Purpose

The purpose of our study was to describe the technical agriculture skills teachers in Illinois and Iowa need to effectively teach courses in the Plant Systems pathway within the broader AFNR Career Cluster. We used the perceptions of knowledgeable, experienced SBAE teachers to accomplish our purpose. It should be noted our study was part of a larger study focused on identifying the technical agriculture skills SBAE teachers in Illinois and Iowa need. Our study specifically addressed the American Association for Agricultural Education (AAAE) National Research Agenda (NRA) Research Priority 3: Sufficient Scientific and Professional Workforce That Addresses the Challenges of the 21st Century (Stripling & Ricketts, 2016).

Methods

We conducted a three-round Delphi study to obtain a general consensus among Illinois and Iowa SBAE teachers regarding their perceptions of the most important technical agricultural skills teachers should have to effectively teach courses in the Plant Systems pathway. Delphi methods have been used in a myriad of recent Agricultural Education studies (Hainline et al., 2019; Rinker et al., 2021; Wells et al., 2021) and serve as an effective tool for building consensus among a panel by using a series of questionnaires (Linstone & Turoff, 1975).

Nomination Process

The careful selection of experts to serve on the panel has been described as the "keystone to a successful Delphi study" (Stitt-Gohdes & Crews, 2004, p. 60). The panelists we used to inform our Delphi study were nominated using a snowball sampling process. We conducted the initial nomination process by reaching out to agricultural teacher educators and state-level SBAE leaders in the two states included in our study. Specifically, we asked these individuals to identify SBAE teachers in their respective state who they perceived to be effective teachers of courses in the Plant Systems pathway. At the conclusion of the initial nomination process, 58 SBAE teachers were nominated to participate in our study. Following the snowball sampling technique, we asked the SBAE teachers who were initially nominated to nominate other teachers who they perceived to be effective teachers of courses in the Plant Systems pathway. At the conclusion of the nomination process, 85 SBAE teachers were nominated to participate in our study as panelists.

Instrumentation / Data Collection

We conducted a three-round Delphi study and used a separate Qualtrics survey instrument to collect data during each round. For each round, we sent an initial survey instrument to the panelists via e-mail. We subsequently sent two reminder e-mails to non-respondents in seven-day increments to increase our response rate. As a reward for their participation in our study, we sent a small refrigerator magnet with the *Teach Ag* logo printed on it to each panelist who responded to our first-round instrument. As we sought to follow the concepts expressed by Dillman et al. (2014), our intention was to motivate panelists to continue responding to our second- and third-round instruments by providing them with a small token of appreciation for their assistance with our scholarly efforts.

Our first-round recruitment e-mail included a description of the study, information regarding the three rounds of the Delphi process, an Institutional Review Board (IRB) -approved informed consent form, and a link to access the first-round instrument. Our first-round instrument was comprised of four items. The first item was an open-ended item that asked the panelists to specify the most important technical agriculture skills teachers need to teach concepts in the Plant Systems pathway. The second item was a multiple-answer question that asked the panelists to specify which previous experiences served as an influence regarding the technical skills they deemed to be important in question one. The multiple-answer item included 19 experiences (e.g., teacher education program coursework or attendance at professional development workshop sessions) for the panelists to select from along with an item that allowed teachers to specify other experiences which were not listed. The third question inquired about the panelists' years of teaching experience. The final item prompted them to nominate other knowledgeable teachers who teach courses in the Plant Systems pathway.

After round one concluded, the panelists identified 129 unique Plant Systems skill items. Our second-round instrument included the 129 skill items compiled in the first round of our study. We asked the panelists to review the 129 skill items and indicate their level of agreement, on a six-point scale (1 = *Strongly disagree*; 2 = *Disagree*; 3 = *Slightly disagree*; 4 = *Slightly agree*; 5 = *Agree*; 6 = *Strongly agree*), regarding the importance for SBAE teachers to have competency with each skill item. We grouped the 129 technical skills and presented them within 10 different categories on the second-round instrument to enhance readability and response efficiency (Dillman et al., 2014). Our 10 skill categories included: (1) Plant Science skills, (2) Business and Communication skills, (3) Equipment, Tool, and Technology skills, (4) General Plant Production skills, (5) Floriculture skills, (6) Plant Propagation skills, (7) Greenhouse and Nursery Management skills, (8) Landscape and Forestry skills, (9) Plant Problem skills, and (10) Soil Science and Agronomy skills.

We sent our second-round instrument only to the 27 panelists who participated in the first round of our study. Twenty-four panelists (response rate = 88.9%) participated in the second round of our study. We set the consensus criteria outlined in Table 1 *a priori* and used these criteria as a metric to determine if each skill item had met consensus amongst the panelists.

Table 1

Consensus Criteria Based on Percentage of Panelists who Indicated a 5 (Agree) or 6 (Strongly agree) on a Given Item

Criteria Decision	%
Met consensus	≥ 75
Included on the third-round instrument for reevaluation	51 to 74
Omitted from further consideration	< 51

Seventy-three of the 129 skill items met consensus in the second round. Fifty-one to 74% of the panelists rated 42 skill items as a 5 (*Agree*) or 6 (*Strongly agree*). These 42 skill items were included on the third-round instrument. Fourteen items fell below the bottom threshold of the consensus criteria and were thus excluded from further consideration.

Our third-round instrument was comprised of 42 skill items. We sent our third-round instrument to the 24 panelists who responded to both our first- and second-round instruments. Eighteen panelists responded to our third-round instrument, yielding a response rate of 75%. Similar to the second round, we asked the panelists to specify their level of agreement with the importance of each skill item using same six-point scale (1 = *Strongly disagree* to 6 = *Strongly agree*). The panelists reached a consensus on nine skill items in the third round; we omitted the remaining 33 skill items from further consideration. At the end of our three-round Delphi study, 82 skill items were considered to have met consensus among the panelists.

Validity and Reliability

We used a panel of experts to review and assess the content validity of our instruments. Our panel of expert members were three agricultural teacher educators at three different land-grant universities across the United States. We asked each panel of expert member to review our instruments, determine the appropriateness of each item, and provide suggestions for the improvement of the instruments. We made augmentations to the instruments (i.e., wording of multiple-answer selections and wording of instrument directions) based on the feedback they each provided. Aside from the establishment of content validity, our implementation of three successive rounds in our Delphi study contributed to concurrent validity of our study as the panelists identified and agreed on the topics over several rounds (Hasson & Keeney, 2011; Sharkey & Sharples, 2001).

In regard to reliability, Dalkey et al. (1972) noted that a 0.70 reliability coefficient could be expected from a Delphi study with a panel of 11 or more members and a Delphi study with 13 or more members would yield a coefficient of 0.90. Based on Dalkey et al.'s (1972) reliability recommendations, the panel size for all three rounds in this study (Round 1, $n = 27$; Round 2, $n = 24$; Round 3, $n = 18$) would be expected to yield reliable findings. While our study meets the threshold of reliability set forth by Dalkey et al. (1972), the establishment of reliability in Delphi studies has been widely disputed (Hasson & Keeney, 2011; Williams & Webb, 1994; Woudenberg, 1991; Yousuf, 2007). Specifically, Woudenberg (1991) contended the Delphi approach yields judgements, not measurements. Judgments are inherently influenced by person-specific and situation specific biases (i.e., factors). We standardized the recruitment procedure, background information, instrument administration techniques, design of the instruments, and the number of rounds to mitigate situation-specific biases. However, we recognize that person-specific biases were present in our study—serving as a key limitation associated with the establishment of reliability.

Data Analysis

We used IBM® SPSS® Statistics Version 26 software to analyze the data we collected in all three rounds of our study. We analyzed the open-ended items on the first-round instrument by organizing the responses into categories and removing any duplicate responses. We calculated measures of central tendency and dispersion, along with frequencies and percentages for the multiple answer and short-answer items in our first-round instrument. We calculated frequencies and percentages to assess if the scale items in the second and third rounds of our Delphi study had met consensus.

Results

Participants

Of the 85 SBAE teachers nominated to participate in our study, 27 agreed to participate as panelists. These panelists had taught an average of 16.63 ($SD = 9.68$) years. We asked each panelist to identify any source of experience that they believed influenced their perceptions of the technical agriculture skills teachers need to teach courses in the Plant Systems pathway. The three influences they most frequently indicated were: "Experiences teaching agricultural education coursework" ($f = 22$; 81.5%), "My experiences with FFA activities (e.g., CDE teams, etc.)" ($f = 18$; 66.7%), and "Attendance at professional development workshop sessions" ($f = 15$; 55.6%; see Table 2).

Table 2

Experiences Influencing Panel Members' Perceptions of the Plant Systems Skills Needed by SBAE Teachers (n = 27)

Experience	*f* (%)
Experiences teaching agricultural education coursework	22 (81.5)
My experiences with FFA activities (e.g., CDE teams, etc.)	18 (66.7)
Attendance at professional development workshop sessions	15 (55.6)
Experiences working in the agricultural industry	14 (51.9)
High school coursework as a student	14 (51.9)
Meetings with industry representatives	12 (44.4)
Early field experiences / observations before student teaching	10 (37.0)
My experiences with student Supervised Agricultural Experiences (SAE)	9 (33.3)
Compliance with mandated course standards	8 (29.6)
Meetings with other agricultural education teachers	8 (29.6)
Teacher education program coursework	7 (25.9)
Meetings with community members	7 (25.9)
Meetings with my current / former students	7 (25.9)
Meetings with my program advisory committee members	4 (14.8)
Meetings with parents / guardians	3 (11.1)
Meetings with my FFA Alumni and supporters	2 (7.4)
Compliance with workforce development data	1 (3.7)
Meetings with other (non-agricultural education) teachers	1 (3.7)
Meetings with my school administrators	1 (3.7)

Conversely, "Compliance with workforce development data" (f = 1; 3.7%), "Meetings with other (non-agricultural education) teachers" (f = 1; 3.7%), and "Meetings with my school administrators" (f = 1; 3.7%; see Table 1) were the experiences the fewest numbers of panelists perceived to influence their perceptions of the technical agriculture skills teachers need to teach courses in the Plant Systems pathway.

Round One

In round one of our study, the panelists provided us with 361 skill items. We disregarded any duplicate responses we received from the panelists, giving us 129 unique skill items for consideration by the panelists in round two. Prior to distributing our second-round instrument, we grouped these items into 10 categories, based upon the nature of the skill item, to improve the readability of our instrument.

Round Two

Using our second-round instrument, we sent the 129 skill items back to the panelists for review. Upon completion of the second round, 73 of the 129 skill items met consensus in round two. At the conclusion of round two, 51 to 74% of the panelists rated 42 skill items as a 5 (*Agree*) or 6 (*Strongly agree*). We subsequently presented these 42 skill items back to the panelists via our third-round instrument. Fourteen items fell below the 51% threshold of the consensus criteria and we thus eliminated them from further consideration prior to round three.

Round Three

Our third-round instrument included 42 skill items. The panelists reached consensus on nine skill items in the third round. Thirty-three items did not meet consensus and were thus removed from our list. At the conclusion of our three-round Delphi study, 82 skill items met consensus among the panelists. All items meeting consensus in rounds two and three are detailed in Table 3 below.

Table 3

Round Two and Three Findings: Plant Systems Skills Needed by SBAE Teachers

Skill Item	*n*	Category	% Agreement
Recordkeeping[a]	24	BCC	95.9
Identifying plant anatomy[a]	24	PS	95.8
Broadcasting landscape inputs (ex. fertilizer, etc.)[b]	18	LF	94.5
Selecting crops[b]	18	GNM	94.4
Transplanting greenhouse crops[b]	18	GNM	94.4
Transplanting plants[a]	24	GPP	91.7
Identifying floral plants[a]	24	FL	91.7
Germinating seeds[a]	24	PP	91.7
Operating greenhouse climate systems[a]	24	GNM	91.7
Using the soil textural triangle[a]	24	SSA	91.7
Identifying plants[a]	24	PS	91.6
Maintaining plants during production (ex. proper watering, etc.)[a]	24	GPP	91.6
Ribbon-testing soil texture[a]	24	SSA	91.6
Conducting soil tests[b]	18	SSA	88.9
Demonstrating plant science principles in a lab setting (ex. photosynthesis, etc.)[a]	24	PS	87.5
Managing a plant production enterprise (ex. greenhouse, etc.)[a]	24	BCC	87.5
Marketing a commodity (ex. corn, etc.)[a]	24	BCC	87.5
Marketing a product (ex. corsages, etc.)[a]	24	BCC	87.5
Organizing plant sales[a]	24	BCC	87.5
Conducting sales (contractual, wholesale, or retail)[a]	24	BCC	87.5
Demonstrating equipment safety procedures[a]	24	ETT	87.5
Calculating fertilizer rates based on formulation available (NPK)[a]	24	GPP	87.5
Selecting plant and seed varieties[a]	24	GPP	87.5
Dividing plants[a]	24	PP	87.5
Purchasing items for greenhouses[a]	24	GNM	87.5
Applying landscape design principles ex. scale, etc.)[a]	24	LF	87.5
Identifying nutrient deficiency[a]	24	PPR	87.5
Skillfully using hand tools[a]	24	ETT	83.4
Tool maintenance[a]	24	ETT	83.4
Harvesting crops[a]	24	GPP	83.4
Using rooting hormones[a]	24	PP	83.4
Collecting soil samples[a]	24	SSA	83.4

Skill Item	*n*	Category	% Agreement
Determining soil organic matter content[a]	24	SSA	83.4
Determining soil nutrient use and loss[a]	24	SSA	83.4
Determining soil structure[a]	24	SSA	83.4
Classifying soils[a]	24	SSA	83.4
Using introductory-level precision agriculture technology (ex. GPS, etc.)[b, c]	18	ETT	83.4
Equipment maintenance[b, c]	18	ETT	83.4
Making bows[b, c]	18	FL	83.3
Making bouquets[b, c]	18	FL	83.3
Maintaining a safe plant laboratory[a]	24	PS	83.3
Conducting customer service procedures[a]	24	BCC	83.3
Calculating profit and loss statements[a]	24	BCC	83.3
Maintaining water supply and irrigation systems[a]	24	GNM	83.3
Creating landscape designs[a]	24	LF	83.3
Calculating area-based estimates for the landscape (ex. mulch, etc.)[a]	24	LF	83.3
Safely using pesticides[a]	24	PPR	83.3
Interpreting a soil test report[a]	24	SSA	83.3
Identifying plant development cycles[a]	24	PS	79.2
Calculating plant genetic probability (ex. Using Punnett Squares, etc.)[a]	24	PS	79.2
Identifying seeds[a]	24	PS	79.2
Using a microscope[a]	24	PS	79.2
Presenting a plant enterprise proposal, design, or plan[a]	24	BCC	79.2
Propagating using cuttings (ex. stem cutting, etc.)[a]	24	PP	79.2
Grafting / budding plants[a]	24	PP	79.2
Stratifying seeds (cold/warm)[a]	24	PP	79.2
Testing seed viability[a]	24	PP	79.2
Growing greenhouse vegetables[a]	24	GNM	79.2
Scheduling crops[a]	24	GNM	79.2
Installing plant materials in the landscape[a]	24	LF	79.2
Installing landscape materials (ex. landscape fabric, etc.)[a]	24	LF	79.2
Interpreting a pesticide label[a]	24	PPR	79.2
Calculating pesticide application rates[a]	24	PPR	79.2
Using a soil probe[a]	24	SSA	79.2
Determining land use[a]	24	SSA	79.2
Determining land slope[a]	24	SSA	79.2
Identifying parts of a plant cell[a]	24	PS	79.1

Skill Item	*n*	Category	% Agreement
Skillfully operating power tools[a]	24	ETT	79.1
Planting crops[a]	24	GPP	79.1
Layering plants[a]	24	PP	79.1
Identifying insects[a]	24	PPR	79.1
Identifying weeds[a]	24	PPR	79.1
Scouting for pests[a]	24	PPR	79.1
Determining soil permeability[a]	24	SSA	79.1
Interpreting data[b, c]	18	PS	77.4
Operating equipment (ex. a tractor, etc.)[a]	24	ETT	75.0
Managing postharvest storage of crops[a]	24	GPP	75.0
Producing floriculture crops[a]	24	GNM	75.0
Developing fertilization regimens (ex. fertilizer timing, etc.)[a]	24	GNM	75.0
Pruning plants[a]	24	LF	75.0
Identifying plant diseases[a]	24	PPR	75.0
Developing an integrated pest management plan[a]	24	PPR	75.0

Note. [a]Item reached consensus in round two; [b]Item reached consensus in round three; [c]Item was not answered by all panelists. 1 = *Strongly disagree*, 2 = *Disagree*, 3 = *Slightly disagree*, 4 = *Slightly agree*, 5 = *Agree*, 6 = *Strongly agree*.

Key for Skill Categories. (1) Plant Science skills = PS, (2) Business and Communication skills = BCS, (3) Equipment, Tool, and Technology skills = ETT, (4) General Plant Production skills = GPP, (5) Floriculture skills = FL, (6) Plant Propagation skills = PP, (7) Greenhouse and Nursery Management skills = GNM, (8) Landscape and Forestry skills = LF, (9) Plant Problem skills = PPS, and (10) Soil Science and Agronomy skills = SSA.

Conclusions, Discussion, and Recommendations

We identified 82 technical agriculture skills teachers in Illinois and Iowa need to effectively teach courses in the Plant Systems pathway within the broader AFNR Career Cluster as described by The Council (2015). In the context of identifying technical agriculture skills needed by SBAE teachers to successfully provide instruction in agricultural subject matter, our findings add to the body of knowledge recently presented by other scholars (e.g., Albritton & Roberts, 2020; Hainline & Wells, 2019; Swafford & Hagler, 2018; Wells et al., 2021).

SBAE stakeholders in Illinois and Iowa should employ the list of 82 technical agriculture skills we identified to help inform the teacher competence development process for their teachers. This could be accomplished by using our defined list of technical agriculture skills as a springboard for discussions and opportunities regarding the preparation of SBAE teachers to engage in Plant Systems pathway-related subject matter. Consideration should be given to the following ideas: (1) the application of professional development workshops targeted toward in-service teachers to provide outlets for continued professional growth and technical agriculture skill development, (2) the exploration and as-needed revision of current agricultural teacher education programs for pre-service teachers to better prepare them to teach technical agriculture skills relevant to courses in the Plant Systems pathway, (3) engagement and partnership with agricultural faculty (e.g., soil scientists, agronomists, plant scientists, etc.) who teach technical agriculture coursework relevant to the Plant Systems pathway within undergraduate degree programs, and (4) the use of our list of technical agriculture skills to further explore professional development needs through follow-up studies specifically designed to do so, similar to the approach used by Wells and Hainline (2021). These efforts could be impactful for ensuring SBAE teachers in Illinois and Iowa are better-able to serve their students through improved preparation to teach technical agriculture skills.

Because we only collected data from teachers in Illinois and Iowa, we do wish to caution that our results are not generalizable beyond these states. Because this is a limitation of our study, we recommend efforts be undertaken to replicate our inquiry in other areas of the United States to better inform the SBAE stakeholders' knowledge regarding the technical agriculture skills needed by teachers to teach courses in the Plant Systems pathway. Concurrent with Wells et al.'s (2021) recommendation, regular replication would help to expand the knowledge base regarding the topic and would help to monitor for changes in teachers' agricultural subject matter-related needs. Moreover, it is worth noting that perhaps a national-level study examining our topic would be useful and practical as well. Doing so would serve a broader number of SBAE stakeholders.

The development of human capital is a lengthy, involved process with many inputs (Swanson & Holton, 2001). Education and training are fundamental components of human capital development (Swanson & Holton, 2001) and the knowledge and experiences of others can be leveraged to help inform how it should occur. As indicated by Wells et al. (2021) and their Agricultural Teacher Education and Agricultural Industry Partnership Model as presented in Figure 2, experienced teachers can serve as wellsprings of knowledge to help inform the teacher competence development process. To learn more about the backgrounds of the experienced teachers who served as panelists in our study, we asked each of them to identify any source of influence which have influenced their perceptions of the technical agriculture skills teachers need to teach courses in the Plant Systems pathway. We found that our panelists most frequently identified sources outside their teacher education programs (e.g., "Experiences teaching agricultural education coursework", "My experiences with FFA activities [e.g., CDE teams, etc.]", "Attendance at professional development workshop sessions", etc.) as more influential than those components within their teacher education programs, such as early field experiences and coursework.

Based upon this finding, we wish to echo the sentiments expressed by Wells et al. (2021), who noted that agricultural teacher education programs may not be fully preparing pre-service teachers with the technical agriculture skills needed to successfully provide instruction in agricultural subject matter. Agricultural subject matter knowledge is a characteristic of effective SBAE teachers (Eck et al, 2019; Roberts & Dyer, 2004), indicating attention to the technical agriculture skill development of SBAE teachers should be a great priority for the profession. Teachers who served as panelists in our study report their perceptions of the technical agriculture skills actually needed to successfully teach courses in the Plant Systems pathways come about through the experiences they had after they started their teaching careers. This indicates teachers are becoming much more informed about the realities of teaching (i.e., the technical agriculture skills they actually need) during the actual practice of teaching in their own programs and engaging in professional development as opposed to during their pre-service teacher education programs. While this observation is probably obvious, we believe it to be important nonetheless.

As we acknowledge that realities about agricultural teacher education programs (e.g., degree program credit hour limitations, requisite state-level approvals of changes to degree programs, etc.) do exist, creativity is needed to ensure pre-service teachers are prepared to step into their own SBAE programs in the near future and teach the technical agriculture skills associated with courses in the Plant Systems pathway. The incorporation of technical agriculture skill development-oriented activities into existing teaching methods courses could be a suitable and cost-effective approach. Moreover, leveraging the practicality of existing early field experiences and student teaching experiences by purposefully placing pre-service teachers alongside in-service teachers who are competent in teaching technical agriculture skills associated with teaching courses in the Plant Systems pathway would be valuable as well.

Bearing in mind the scope of developing human capital, perhaps the most significant of the requisite inputs is education (Sweetland, 1996), which can occur through various formal and non-formal means for teachers (e.g., completing undergraduate-level plant science courses as part of an agricultural teacher education program, informally working with a more experienced teacher in a neighboring school district to learn additional technical agriculture skills, etc.). Considering the need to continue developing the agricultural workforce of the 21st century (Stripling & Ricketts, 2016) and the roles SBAE teachers play in their students' own personal and professional growth (Phipps et al., 2008), it is imperative teachers be as prepared and competent as possible to engage in their agricultural subject matter. Moreover, evidence suggests both teacher liability concerns (Love, 2013) and teacher retention issues (Solomonson et al., 2018) can perhaps be mitigated by ensuring teachers are appropriately trained and prepared in their subject matter. Doing so could also positively impact the very significant issue of SBAE teacher retention, which is of great concern for the long-term sustainability, growth, and impact of SBAE programs (Foster et al., 2020).

References

Albritton, M. C., & Roberts, T. G. (2020). Agricultural technical skills needed by entry level agriculture teachers: A modified Delphi study. *Journal of Agricultural Education, 61*(1), 140-151. https://doi.org/10.5032/jae.2020.01140

Baye, M. R., & Prince, J. T. (2014). *Managerial economics and business strategy*. McGraw-Hill/Irwin.

Clemons, C. A., Heidenreich, A. E., & Lindner, J. R. (2018). Assessing the technical expertise and content needs of Alabama agriscience teachers. *Journal of Agricultural Education, 59*(3), 87- 99. https://doi.org/10.5032/jae.2018.03087

Dalkey, N. C., Rourke, D. L., Lewis, R., & Snyder, D. (1972). *Studies in the quality of life*. Lexington Books.

Darling-Hammond, L. (2003). Keeping good teachers: Why it matters, what leaders can do. *Educational Leadership*, *60*(8), 6-13. http://www.ascd.org/publications/educational-leadership/may03/vol60/num08/Keeping-Good-Teachers@-Why-It-Matters,-What-Leaders-Can-Do.aspx

Darling-Hammond, L., Chung, R., & Frelow, F. (2002). Variation in teacher preparation: How well do different pathways prepare teachers to teach? *Journal of Teacher Education, 53*(4), 286-302. https://doi.org/ 10.1177/0022487102053004002

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.

Doerfert, D. L. (Ed.) (2011). *National research agenda: American Association for Agricultural Education research priority areas for 2011-2015*. Texas Tech University, Department of Agricultural Education and Communications.

Easterly, R. G., III, & Myers, B. E. (2017). Characteristics of enthusiastic and growing school-based agricultural education teachers: A Delphi approach. *Journal of Agricultural Education, 58*(2), 1-19. https://doi.org/10.5032/jae.2017.02001

Eck, C. J., Robinson, J. S., Ramsey, J. W., & Cole, K. L. (2019). Identifying the characteristics of an effective agricultural education teacher: A national study. *Journal of Agricultural Education, 60*(4), 1-18. https://doi.org/10.5032/jae.2019.04001

Figland, W., Blackburn, J., Stair, K., & Smith, E. (2019). What do they need? Determining differences in the professional development needs of Louisiana agriculture teachers by years of teaching experience. *Journal of Agricultural Education, 60*(2), 173-189. https://doi.org/10.5032/jae.2019.02173

Foster, D. D., Lawver, R. G., & Smith, A. R. (2020). *National agricultural education supply & demand study: 2019 executive summary*. https://aaaeonline.org/resources/Documents/NSD2019%20Summary_7.15.20.pdf

Hainline, M. S., Burris, S., Ulmer, J. D., & Ritz, R. A. (2019). School district superintendents' and attorneys' perceptions of the most important educational law issues impacting agricultural science teachers. *Journal of Agricultural Education, 60*(2), 190-209. https://doi.org/10.5032/jae.2019.02190

Hainline, M. S., & Wells, T. (2019). Identifying the agricultural mechanics knowledge and skills needed by Iowa school-based agricultural education teachers. *Journal of Agricultural Education, 60*(1), 59-79. https://doi.org/10.5032/jae.2019.01059

Hasson, F., & Keeney, S. (2011). Enhancing rigour in the Delphi technique research. *Technological Forecasting and Social Change*, *78*(9), 1695-1704. https://doi.org/10.1016/j.techfore.2011.04.005

Haynes, M. (2014). *On the path to equity: Improving the effectiveness of beginning teachers.* https://all4ed.org/reports-factsheets/path-to-equity

Hendrix, R., & Morrison, C. C. (2018). Student perceptions of workforce readiness in agriculture. *Journal of Agricultural Education, 59*(3), 213-228. https://doi.org/10.5032/jae.2018.03213

Ingersoll, R. & Smith, T. (2003). The wrong solution to the teacher shortage. *Educational Leadership, 60*(8), 30-33.

Linstone, H. A., & Turoff, M. (Ed.). (1975). *The Delphi method: Techniques and applications*. Addison Wesley Publishing Company.

Love, T. S. (2013). Addressing safety and liability in STEM education: A review of important legal issues and case law. *The Journal of Technology Studies, 39*(1), 28-42. https://doi.org/10.21061/jots.v39i1.a.3

Lutz, W., & KC, S. (2011). Global human capital: Integrating education and population. *Science, 333*(6042), 587-592. doi:10.1126/science.1206964

McDaniel, T. R. (2020). Corporal punishment and teacher liability: Questions teachers ask. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 93*(2), 10-13. https://doi.org10.1080/00098655.2020.1729640

The National Council for Agricultural Education (2015). *AFNR career cluster content standards*. https://ffa.app.box.com/s/n6jfkamfof0spttqjvhddzolyevpo3qn/file/294160068843

Phipps, L. J., Osborne, E. W., Dyer, J. E., & Ball, A. (2008). *Handbook on agricultural education in public schools* (6th ed.). Thomson Delmar Learning.

Rinker, S. P., Smalley, S. W., & Hainline, M. S. (2021). Identifying the professional and technical skills agricultural industry employers expect agricultural graduates to possess. *NACTA Journal, 65*(1), 102-114. https://www.nactateachers.org/attachments/article/3112/2020-0200 FINAL.pdf

Roberts, T. G., & Ball, A. L. (2009). Secondary agricultural science as content and context for teaching. *Journal of Agricultural Education, 50*(1), 81-91. https://doi.org/10.5032/jae2009.01081

Roberts, T. G., & Dyer, J. E. (2004). Characteristics of effective agriculture teachers. *Journal of Agricultural Education, 45*(4), 82-95. http://doi.org/10.5032/jae.2004.04082

Robinson, J. S., & Baker, M. A. (2013). The effect of human capital on principals' decisions to interview candidates in agricultural education: Implications for pre-service teachers. *Journal of Agricultural Education, 54*(1), 139-152. http://doi.org/10.5032/jae.2013.01139

Robinson, J. S., & Garton, B. L. (2008). An assessment of the employability skills needed by graduates in the college of agriculture, food and natural resources at the University of Missouri. *Journal of Agricultural Education, 49*(4), 96-105. https://doi.org/10.5032/jae.2008.04096

Saucier, P. R., Vincent, S. K., & Anderson, R. G. (2014). Laboratory safety needs of Kentucky school-based agricultural mechanics teachers. *Journal of Agricultural Education, 55*(2), 184-200. https://doi.org/10.5032/jae.2014.02184

Sharkey, S. B., & Sharples, A. Y. (2001). An approach to consensus building using the Delphi technique: Developing a learning resource in mental health. *Nurse Education Today*, *21*(5), 398-408. https://doi.org/10.1054/nedt.2001.0573

Shoulders, C. W., & Myers, B. E. (2012). Teachers' use of agricultural laboratories in secondary agricultural education. *Journal of Agricultural Education, 53*(2), 124-138. https://doi.org/10.5032/jae.2012.02124

Smalley, S. W., Hainline, M. S., & Sands, K. (2019). School-based agricultural education teachers' perceived professional development needs associated with teaching, classroom management, and technical agriculture. *Journal of Agricultural Education, 60*(2), 85-98. https://doi.org/10.5032/jae.2019.02085

Solomonson, J. K., Korte, D. S., Thieman, E. B., Retallick, M. S., & Keating, K. H. (2018). Factors contributing to Illinois school-based agriculture teachers' final decision to leave the classroom. *Journal of Agricultural Education*, *59*(2), 321-342. https://doi.org/10.5032/jae.2018.02321

Stitt-Gohdes, W. L., & Crews, T. B. (2004). The Delphi technique: A research strategy for career and technical education. *Journal of Career and Technical Education, 20*(2), 55-67. https://files.eric.ed.gov/fulltext/EJ1069510.pdf

Stripling, C. T., & Ricketts, J. C. (2016). Research priority 3: Sufficient scientific and professional workforce that addresses the challenges of the 21st century. In T. G. Roberts, A. Harder, & M. T. Brashears. (Eds.), *American Association for Agricultural Education national research agenda: 2016-2020.* Department of Agricultural Education and Communication.

Swafford, M., & Hagler, P. (2018). Beginning SBAE teachers' metal fabrication knowledge needs: Implications for teacher preparation. *Journal of Agricultural Education, 59*(1), 287-296. https://doi.org/10.5032/jae.2018.01287

Swanson, R. A., & Holton, E. F. (2001). *Foundations of human resource development* (2nd ed.). Berrett-Kohler.

Sweetland, S. R. (1996). Human capital theory: Foundations of a field of inquiry. *Review of Educational Research, 66*(3), 341-359. https://doi.org/10.3102/00346543066003341

Wells, T., & Hainline, M. S. (2021). Examining teachers' agricultural mechanics professional development needs: A national study. *Journal of Agricultural Education, 62*(2), 217-238. https://doi.org/10.5032/jae.2021.02217

Wells, T., Hainline, M. S., Rank, B. D., Sanders, K. W., & Chumbley, S. B. (2021). A regional study of the agricultural mechanics knowledge and skills needed by school-based agricultural education teachers. *Journal of Agricultural Education, 62*(2), 148-166. https://doi.org/10.5032/jae.2021.02148

Whittington, M. S. (2005). The presidential address to the Association for Career and Technical Education Research: Using standards to reform teacher preparation in career and technical education: A successful reformation. *Career and Technical Education Research, 30*(2), 89-99. https://www.ctc.ca.gov/docs/default-source/educator-prep/cte-files/cte-research-presidential-address.pdf

Williams, P. L., & Webb, C. (1994). The Delphi technique: A methodological discussion. *Journal of Advanced Nursing*, *19*(1), 180-186. https://doi.org/10.1111/j.1365-2648.1994.tb01066.x

Woudenberg, F. (1991). An evaluation of Delphi. *Technological Forecasting and Social Change, 40*(1), 131-150. https://doi.org/10.1016/0040-1625(91)90002-W

Yousuf, M. I. (2007). Using experts' opinions through Delphi technique. *Practical Assessment, Research, and Evaluation*, *12*(1), 1-8. https://doi.org/10.7275/rrph-t210

Zirkle, C. (2017). An introduction to liability for technology and engineering teachers. *Technology and Engineering Teacher, 76*(7). https://www.questia.com/library/journal/1G1- 499277882/an-introduction-to-liability-for-technology-and-engineering