Assessing Teacher Practices Related to Precision Agriculture in Secondary Agriculture Education

Abigail E. Heidenreich
Purdue University Cooperative Extension
aheidenr@purdue.edu

Christopher A. Clemons
Auburn University
cac0132@auburn.edu

James R. Lindner
Auburn University
jrl0039@auburn.edu

Wheeler Foshee
Auburn University
foshewg@auburn.edu

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Abstract

Agricultural education was designed to reflect the agriculture industry, and since the recent increase in technology use in the industry, little research has been done to investigate what agricultural technologies are used in secondary agriculture classrooms. Secondary agriculture instructors in Alabama and Illinois participated in this study and provided descriptive data about their personal characteristics and their decision to incorporate precision agriculture, as well as barriers that prevent them from incorporating precision agriculture concepts. This study identifies the curriculum involving precision agriculture that is currently being taught and gains insight into teachers' decisions to integrate precision agriculture in their classrooms. Teachers indicated the importance and relevance of precision agriculture, but only half of the participants incorporate related concepts into their curricula. A Chi Square test revealed no significant relationships between the personal characteristics of teachers and their decision to incorporate precision agriculture concepts. The most important topics in precision agriculture were identified by participants as: GPS, Soil Sampling/Land Management and Genetic Modification. Teachers indicated a need for professional development or teacher education focused on precision agriculture in multiple fashions and supports the need for similar education in the agriculture industry.

Introduction

Agriscience education is a lifelong journey of instilling foundational content skills, developing experiential learning opportunities for a well-trained 21^{st} century student, and focused professional development for the agriscience teaching profession. Secondary agricultural educators have consistently demonstrated interest and value in promoting agricultural technologies for student learning. Agriscience educators have been urged to push the bounds of instructional innovation for over 115 years as reported by Wallace's Farmer (1908) and cited by Hillison (1995) "if the director could introduce the teacher to lay aside the book and present problems likely to come up in farm life, it would tend to make a good deal better farmer[s] out of the next generation" (p. 8). Although the statement was limited to traditional agriculture students of the early 1900's the pragmatic context is just as profound today. Understanding practices and rationale for the inclusion of precision agriculture content in new and existing curricula may serve as a model for other programs and schools seeking to enhance the practicality of today's modern agricultural education classroom. Precision agriculture inclusion is a vital component of instructional innovation in the secondary agriscience education classroom (Palak & Walls, 2009) and requires a unique set of teaching and learning competencies to reflect historical agricultural changes (Ruffing, 2006). Identifying the tenets that promote or inhibit the adoption of innovation (Rogers, 2003) relating to precision agriculture content in the secondary agriscience classroom is vital to continued growth and success of global agriculture. Glenn (1997) wrote "public support for technology instruction is strong and vocal, and there is an expectation that no school can prepare students for tomorrow's society of new technologies are not available for students" (p. 123). To understand the perceptions of secondary agriscience education teachers' instruction of precision agriculture we need to understand the rationale in which precision agriculture content is embedded in agriscience curricula. Identifying the relevance of precision agriculture in existing course pathways will explain the perceived importance of precision agriculture instruction to secondary agriscience teachers. Determining the perceptions and barriers of the curricula associated with precision agriculture instruction as described by Kotrlik et al. (2003) may identify detractors limiting precision agriculture content in agriscience courses.

McBratney et al. (2005) defined precision agriculture as “the[sic] kind of agriculture that increases the number of (correct) decisions per unit of area of land per unit of time with associated net benefits” (p. 8). Precision agriculture has been characterized as using standardized methods such as crop rotation and fertilizer application to increase yields. Advances in information technology have created the opportunity to farm in a more customizable way that allows agricultural producers to make informed management decisions (Lowenberg-DeBoer, 2015). Consumer demands for efficiency and environmental conscientiousness in agriculture have reduced inputs, increased efficiency, and improved yields. These practical applications shape the agricultural industry into a sustainable and efficient production model for the growing population. Global positioning systems, soil mapping, variable rate planting, unmanned aerial vehicles, and yield mapping represent new and emerging technologies and serve as an opportunity for inclusion in secondary agriscience education classrooms. Kotrlik et al. (2003) reported the difficulty of integrating technology instruction in secondary agriscience education classrooms as difficult, time consuming, and resource intensive.

The training and education for consumers of technology as well as specialists who are able to install, troubleshoot, maintain, educate, and develop emerging technology is increasing in demand. Kitchen et al. (2002) reported a lack of sufficient and effective education opportunities for producers, teachers, and students of precision agriculture technologies exist in modern training programs. Existing research has described the many challenges of technology adoption among agricultural producers, agriscience teachers, and students (Ertmer, 1999; Redmon et al., 2003; Smith et al., 2018). As new technologies emerge instructional methods must evolve to ensure career readiness for agriscience education students. Budin (1999) stated technology instruction should be reconceptualized regarding the specifics of how technology fits in the curriculum knowledge requirements for instructional delivery, and the assessment of technology instruction for students learning. Wood et al. (2005) identified five factors attributed to the hesitation of integrating and adopting technology in the secondary agriscience classroom: lack of support, restricted technical access, student application issues, technical problems, and teacher’s attitudes and perceptions integrating technology in curricula. The benefits of incorporating technology in the secondary classroom have been studied extensively (Gorder, 2008) while Clemons et al. (2018) reported professional development in agricultural technology and STEM instruction was a continuing area of need for secondary teachers. Educational integration of precision agriculture and STEM applications in secondary agriculture classrooms benefit students through practical application and career preparation. Prior research indicated positive relationships between the use of STEM and agricultural classrooms. Smith et al. (2015) outlined the relationships between STEM and agriculture, noting that “agriculture teachers are confident in their ability to integrate science concepts…students who engage in math integrated agricultural power and technology class scored higher on a postsecondary math placement test” (p. 182-201). Many agriculture teachers unknowingly incorporate STEM into the existing agriscience education curricula . As agricultural technologies emerge, finding ways to incorporate precision agriculture topics that include STEM principles will not pose a challenge to teachers (Stubbs & Myers, 2016).

Although teacher self-efficacy regarding best pedagogical methods for STEM instruction could be an issue requiring enhance professional development. Many precision agriculture concepts already encompass science, technology, engineering, and mathematics. The combination of technology uses to solve specific problems are endless; engineering and mathematical components of precision agriculture technologies are necessary for the technology itself to function and can easily be investigated by students in a variety of settings and course topics. The flexibility of precision agriculture technologies across topics and educational structures is an enormous asset to teachers who choose to incorporate them into their coursework.

Conceptual Framework

Rogers' (2003) Diffusion of Innovation Theory is comprised of four components: innovation, communication channels, time, and social systems. The innovation element of Diffusion of Innovation Theory is composed of ideas that are considered new or emerging practices. Technology concepts are often innovative ideas and follow the Diffusion of Innovation Theory as people develop new ways to utilize technology.

Rogers (2003) discusses how homophily and heterophily affect the spread of ideas, stating that ideas flow more freely among homophilous individuals: individuals who are similar and work together towards mutual goals. Heterophilous individuals tend to be quite different from each other and therefore have a more difficult time communicating and agreeing on the importance of ideas and innovations. Time is considered by Rogers (2003) to be the measurement tool of the entire process of learning about innovations to adopting them. The innovation-decision process consists of an individual's course of learning over time that begins with learning of an innovation, learning about the innovation, forming an opinion on the innovation, and results in either adoption or rejection of the innovation (Rogers, 2003).

Social systems are the final component of Rogers' Diffusion of Innovation Theory. Social systems can be characterized as networks of individuals or units working together to accomplish a common goal, often groups of people or organizations. The leadership of some individuals or the normality of the group affect the flow of information and how it reaches individuals (Rogers, 2003). This element shares many characteristics with the idea of human capital, which describes how individual's professional and personal networks affect their decision-making process (Hunecke et al., 2017).

Rogers' Diffusion of Innovation Theory develops the process of innovation adoption and describes how groups of individuals within a social system can be identified based on the time it takes them to adopt innovations and the attributes that commonly affect their decision-making process. These categories are innovators, early adopters, early majority, late majority, and laggards (Rogers, 2003). Innovators, individuals who are comfortable with uncertainty, are capable of higher-level thinking in regards to concept application. Early adopters are characterized as being slightly more contemplative than innovators and, are led by their opinions on the innovation and, evaluate the innovation subjectively. Individuals that comprise the early majority group rarely lead the way and are willing to adopt innovations. Early majority individuals often take longer than both innovators and early adopters to contemplate adoption of innovations and rely on their predecessor adopters for signs of success. Late majority adopters are cautious by nature and rely heavily on social norms to sway their decisions. They require little uncertainty surrounding the innovation in question. In comparison, laggards are the last group to adopt innovation. Laggards resist innovation adoption and often doubt the success of an innovation, exercising acute caution in the decision-making process.

The characteristics of innovation adopters described in Rogers' (2003) Diffusion of Innovation Theory are similar to attributes that influence decisions, intentions, and behaviors described in Fishbein and Ajzen's (1975) Theory of planned behavior. Fishbein and Ajzen (1975) stated that an "individual's intention to perform a behavior (behavior x) is influenced by their attitudes towards that behavior as well as their beliefs about the consequences of that behavior" (p. 16). Intention to perform a behavior (behavior x) is also influenced by subjective norms and normative beliefs about that behavior (Fishbein & Ajzen, 1975). The confluence of these theories considers behavior x to be the adoption of an innovation or idea.

Individuals are influenced by their attitudes and beliefs towards adopting new innovations (Fishbein & Ajzen, 1975). A similar example could be found with the opposite result, utilizing an innovator or early adopter as the instructor or individual. This individual's attitudes and beliefs towards adopting new ideas are positive, therefore they are more likely to incorporate precision agriculture technology into their coursework.

Purpose and Objectives

This study investigated agriscience teacher perceptions of curriculum involving precision agriculture technology and their insights regarding the integration of agricultural technology curriculum. The objectives of this study were: describe the courses and curriculum currently being used to teach precision agriculture concepts, describe the most important topics in precision agriculture and the relevance of precision agriculture in the areas of education and agriculture, describe potential relationships between participant personal characteristics and their incorporation of precision agriculture concepts in their classrooms, and describe the barriers that may prevent teaching precision agriculture.

Methods

The target population for this study were certified agriscience teachers in Alabama (N = 302) and Illinois (N = 391). Participants were identified using a contact data base provided by the professional agricultural education organizations in each state. Participants were randomly selected from each state using Cochran's (1977) theorem, Alabama (n = 169) and Illinois (n = 196) for appropriate sample size. Characteristics of the study participants included 60 male teachers (73.2%) and 22 female (26.8%) teachers with 69 (84.1%) indicating rural school location, 12 (14.6%) from suburban schools, and 1 (1.2%) from urban areas. Participants' teaching experienced ranged from 0-5 years (n = 22, 26.8%) 6-10 years (n = 21, 25.6%), 11-20 years (n = 16, 19.5%), 21-30 years (n = 18, 22) and greater than 30 years (n = 5, 6.1%). The final questionnaire was distributed to 373 participants with (n = 37) from Alabama and (n = 36) from Illinois yielding a 24.00 questionnaire response rate. Three attempts were made through email and two telephone conversations to increase the response rate. The total response rate was 88 completed questionnaires; however, 15 participants did not indicate their state. Non-response bias was addressed through oversampling 20% of the available population. Using Lindner et al. (2001) method 3 analysis and comparison of early versus late respondents was conducted using a t-test (Table 1) which did not identify any significant differences between timing and data results.

Table 1

Comparison of Early and Late Respondents

Statement	*t*	*df*	*Sig 2-tailed*
Relevance of Precision Ag in Agriculture Job Market	1.64	79	.11
Competence	1.49	86	.14
Relevance of Precision Ag in Coursework/Content	0.82	80	.42
Relevance of Precision Ag in Agriculture Industry	0.75	80	.45
Relevance of Precision Ag in Classroom Technology	.70	80	.48
Importance	.260	86	.80
Incorporation of Precision Agriculture	0.00	86	1.00

The review of existing literature did not identify an instrument appropriate for this study. Development of the questionnaire was completed by the researcher, two academic faculty in the agriscience education field, and an agriculture and natural resources extension agent. During the development of the instrument, fifteen preliminary research statements were selected to address participant perceptions of precision agriculture and potential barriers to incorporating precision topics and eighteen items to collect participant characteristics. Internal validity of the questionnaire was addressed by the instrument development team and eight individuals were selected to participate in a pilot test from (N = 4) from Alabama and (N = 4) from Illinois. Pilot study participants were representative of the population, but were not included in the sample of the population utilized for the study. The individuals selected to provide feedback in the pilot test were selected by the researcher based on their knowledge of research and their likeliness to provide honest and applicable analysis of the instrument. Pilot study participants were asked to review the instrument and provide input on the potential ambiguity of statements, sentence structure and other changes that may be necessary. Results from the pilot test indicated necessary changes to the instrument including ambiguity of specific statements and organization of the overall survey instrument. The analysis of data utilized descriptive statistics for describing the sample personal characteristics in each state. Borich’s (1980) analysis was conducted to measure participants confidence and level of importance related to precision agriculture concepts and willingness to include precision agriculture in the curriculum. To further understand if a relationship existed between observed categorical values and theoretical expectations, a Chi Square for Goodness of Fit analysis was conducted.

Findings

Objective one sought to describe the courses and curriculum containing units or lessons pertaining to precision agriculture. Participants indicating their incorporation of precision agriculture were asked to identify courses they teach which contain units or lessons pertaining to precision agriculture (Table 2). The results indicated that 27 respondents (61.0%) incorporate precision agriculture concepts in introduction to agriculture, 16 (36.0%) in agribusiness courses, and *n* =13 (30.0%) incorporated precision agriculture in horticulture classes. Other courses were identified by respondents as agronomy, ag science, general agriculture, plant biology, ag sales and marketing, physical science applications in agriculture, crop and soil science, and advanced agriculture. Animal science and agricultural construction accounted for *n* = 8 (18.0%) respectively. Agricultural leadership courses, *n* = 5 (11.0%), forestry courses, *n* = 4 (9.0%), aquaculture courses, *n* = 2 (5.0%), and *n* = 11 (2.0%) in Cooperative Classes reported significantly less incidences of curriculum inclusion.

Table 2

Courses representing the inclusion of units or lessons pertaining to precision agriculture.

Courses in Agriscience Classrooms containing Precision Agriculture	*f*	%
Introduction to Agriculture	27	61
Agribusiness	16	36
Horticulture	13	30
Ag Mechanics	13	30
Other	13	30
Animal Science	8	18
Ag Construction	8	18
Agricultural Leadership	5	11
Forestry	4	9
Aquaculture	2	5
Cooperative Class	1	2

Participants were organized according to their incorporation of precision agriculture instructional materials within existing curricula (Table 3). The greatest number of participants (*n* = 26, 59.0%) indicated self-created curriculum materials were used for the instruction of high school agriscience teachers. Online resources (*n* = 23, 52.0%), hands on technology (*n* = 20, 45.0%), textbook (*n* = 14, 32.0%), purchased/packaged curriculum (*n* = 10, 22.0%), and “other” (*n* =3, 6.0%) were indicated as resources. The use of simulators (*n* = 2, 4.0%) was the least used type of instructional materials.

Table 3

Curriculum Resources Most Often Utilized In Precision Agriculture Instruction

	Resources most commonly used	
Resources	*f*	%
Self-created curriculum	26	59.0
Online resources	23	52.0
Hands on technology	20	45.0
Textbook	14	32.0

Purchased/packaged curriculum	10	22.0
Other	3	6.0
Simulators	2	4.0

Participants indicated their perceptions related to the future of precision agriculture instruction. Participants were provided four statements (Table 4) pertaining to education in their classroom or in agriculture and indicated their opinion of relevance 5-10 years in the future on a scale from 5, extremely relevant, 4, somewhat relevant, 3, no change in relevance from today, 2, somewhat irrelevant, and 1, extremely irrelevant. Participants perceptions of future instruction in precision agriculture were overwhelmingly relevant for future employment opportunities for students. In their classroom technologies, 96% of teachers indicated that precision agriculture topics were either extremely relevant or somewhat relevant. Teacher perceptions of the most important topics involving precision agriculture were analyzed depending on their incorporation of precision agriculture concepts in their classrooms. Teachers who indicated their incorporation of precision agriculture in their classrooms identified the most important topics as 20.9% (GPS), 20.9% (soil sampling or land management), 14.0% (variable rate technology), 9.3% (yield monitoring), 4.7% (automated production Systems), 4.7% (unmanned aerial systems or vehicles), 23.3% (genetic modification), 2.3% (chemical technology), and 0% (Satellite Imaging).

Table 4

Topics of Secondary Agriscience Instructional Importance in Precision Agriculture

Topics of Importance	Incorporate Concepts		Do Not Incorporate Concepts	
	f	%	*f*	%
Global Positioning Systems	9	20.9	11	28.9
Genetic Modification	10	23.3	8	21.1
Soil Sampling/Land Management	9	20.9	7	18.4
Variable Rate Technology	6	14.0	4	10.5
Yield Monitoring	4	9.3	2	5.3
Automated Production Systems	2	4.7	2	5.3
Unmanned Aerial Systems/Vehicles	2	4.7	2	5.3
Satellite Imaging	0	0	2	5.3
Chemical Technology	1	2.3	0	0
Other	0	0	0	0
Total	43	100	38	100

Teachers indicating no inclusion of precision agriculture concepts in their classrooms identified the most important topics (Table 5) in precision agriculture as: 28.9% (GPS), 21.1 % (genetic modification), 18.4 % (soil sampling or land management), 10.5 % (variable rate technology), 5.3 % (satellite imaging), 5.3 % (yield monitoring), 5.3 % (automated production systems), 5.3 % (unmanned aerial systems or vehicles). Participants not currently teaching precision agriculture reported chemical technology as not important for instruction.

Table 5

Participants Perceptions of Future Relevance of Precision Agriculture Topics

	Extremely Relevant		Somewhat Relevant		No Change in Relevancy		Somewhat Irrelevant		Extremely Irrelevant	
Areas of Relevance	*f*	%	*f*	%	*f*	%	*f*	%	*f*	%
Agriculture Industry	72	88	10	12	0	0	0	0	0	0
Agriculture Employment	61	75	20	25	0	0	0	0	0	0
In Classroom Technologies	46	56	33	40	3	4	0	0	0	0
Coursework/Content	35	43	43	52	4	5	0	0	0	0

A chi-square goodness of fit test was used to identify the potential for relationships that may exist between the participants' personal characteristics and their decision to incorporate precision agriculture concepts into their curricula (Table 6). A significant relationship would signify that a personal characteristic would have an effect on their decision to incorporate precision agriculture. The results of this objective did not identify any significant relationships between participant personal characteristics and their decision to incorporate precision agriculture concepts into their curricula.

Table 6

Contingency Table by Personal Characteristics and Incorporation of Precision Agriculture Topics

Personal characteristics	*n*	*df*	*Sig*
Age	80	4	.91
Years teaching	82	4	.87
Gender	82	1	.79
State	73	1	.72
Education level	82	2	.42
School location	82	2	.34
Student enrollment	81	2	.13

Conclusions, Implications, and Recommendations

Agriculture teachers indicated limited integration (50.0%) of precision agriculture instruction within their existing curriculum. This finding supports Rogers (2003) findings that individuals will adopt innovative approaches in a timely manner, while others may resist implementation because of doubt related to the potential for success of the innovation. Participants (50%) in this study reported their interest in curricula integration would best be described as innovators; those demonstrating higher order thinking in relation to adoption of concepts to application. Participants indicating the incorporation of precision agriculture concepts occurred in traditional secondary agriscience courses: introduction to agriculture, agribusiness, ag mechanics, and horticulture. In comparison, participants identified potential barriers to integration: funding, equipment, curriculum, experience, and professional development. These findings support the barriers of technology reported by Wood et al. (2005).

The participants indicated their most important topics in precision agriculture as GPS, soil sampling/land management, and genetic modification. Teachers also described the resources they use as their curricula, resulting in the most common resources being self-created curriculum (59%), online resources (52%), and hands-on technology (45%). When asked about their perception of the future relevance of precision agriculture in their classrooms and in their coursework, participants indicated extremely relevant, somewhat relevant or “no change in relevance from today. Fishbein and Ajzen (1975) postulated the means in which individuals’ intention to perform a behavior is influenced by their attitudes towards the consequences of the behavior. The conclusions of this study support the theory of planned behavior at the various levels of integrating precision agriculture related curricula. When asked the relevance of precision agriculture topics in the agriculture industry and in the agriculture job market, participants reported precision agriculture being extremely relevant or somewhat relevant in 5-10 years. Participant support coupled with forecasting future trends in agricultural employment arenas tended to be positive. Participants perceived value in precision agriculture curricula while respecting the role this content will have in their student’s future employment.

Participants identified the most important lessons for integrating precision agriculture curriculum regardless of their decision to incorporate precision agriculture into their curricula: GPS, Soil Sampling/Land Management, and Genetic Modification. Participants were asked to indicate the relevance of precision agriculture 5-10 years in the future in four areas: (in your classroom, in your coursework/content), 61.0% indicated their perception of precision agriculture as “extremely relevant” while 39.0%indicated precision agriculture being either “somewhat relevant” in the future or “no change in relevance from today. Participants overwhelmingly agreed (75.0%) that precision agriculture will be valued in the agriculture industry and in the agriculture job market while 25.0% indicated precision agriculture being somewhat relevant 5-10 years in the future. Participants indicating hesitation to the level of relevance may be reflective of Wood et al. (2005) suggesting factors associated with technology integration in agricultural education programs.

It is recommended that further research focusing on precision agriculture in agriculture education be conducted. This recommendation supports the findings of Glenn (1997) by advocating for public support related to technology instruction in public school systems. As the agriculture industry grows and advances, so should agriculture education and research efforts. The identification of possible content areas or educational concepts to better prepare students entering careers in precision agriculture, should be investigated and include individuals currently pursuing careers in precision agriculture. By comparing the education patterns of those who currently hold careers in precision agriculture, preparatory education could become more specific and therefore more beneficial to those wishing to enter a career in precision agriculture.

A need exists for professional development and teacher education focusing on precision agriculture and was supported by Palak and Walls (2009). Future studies should identify specific areas within precision agriculture that would be most beneficial to teachers and, in turn, their students. This recommendation may be limited by what (Ertmer, 1999; Redmon et al., 2003; Smith et al., 2018) reported as challenges associated with technology adoption among agriculturalists. A compilation of resources for teachers to use in building curriculum is needed. Reliable information that is accurate and representative of what occurs in the agriculture industry should be gathered and presented to teachers for use in their classrooms and should be updated annually to best reflect the technologies used in the agriculture industry. Similarly, partnerships between agriculture education and the companies that specialize in precision agriculture technologies should be formed so that teachers are equipped with the tools needed to educate their students. These industry partners are imperative to keeping secondary agriculture education relevant and sparking the interest of students to work in the agriculture industry.

Precision agriculture is a progressive and emerging topic in agriculture that is facing farmers with the decision to either move with the flow of technology or get left behind. Many people within agriculture, let alone outside the field, do not understand precision agriculture or what it entails. This leads to confusion, misinformation and general misconceptions surrounding the topic of precision agriculture, which underlines the importance of familiarizing future agriculturalists with the precision-rich agricultural future they are to inherit. Precision agriculture can be identified in various arenas: innovative technology development and the application of technology in real life. We, as agricultural educators, must do our part in educating agriculturalists on the best practices for applying this emerging technology to its respective goal. Secondary agriculture educators work with students who live in this agriculturally rich world every day, they are our connection to the future of agriculture. By incorporating precision agriculture technologies that are already being used in agriculture, students will be better prepared.

Teaching students to care for the environment is becoming prevalent in secondary agricultural education curriculum and precision agriculture content would be the next evolutionary step. Environmental science and stewardship practices define a component of production agriculture education and the inclusion of concepts which provide data based and technological components reinforce environmental science curriculum. The implications of combining precision agriculture and environmental science will aid in the development of students STEM processes and the ability to implement STEM practices in a meaningful and productive manner. Continuing education for practicing agricultural education teachers should contain concepts and instruction in precision agriculture. Professional development opportunities would allow teachers to become more comfortable with the content and in the development of standalone modules or incorporation of precision agriculture concepts within existing curriculum. Agricultural education teachers should be provided pre-service training through Colleges of Agriculture or preparatory work in Colleges of Education as familiarity with the content would reduce anxiety and doubt for younger teachers and give direction to veteran teachers looking to update their course materials.

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