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Knowledge, Skills, and Abilities in the Precision Agriculture Workforce: An Industry Survey

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Bruce Erickson,* Scott Fausti, David Clay, and Sharon Clay

Abstract

Precision agriculture encompasses a set of related technologies aimed at better utilizing crop inputs, increasing yield and quality, reducing production risks, and enabling information flow throughout the crop supply and end-use chains. As agricultural businesses invest in precision offerings, their capacity to provide these products and services will depend on their ability to hire and retain employees with appropriate proficiency as defined in their knowledge, skills, and abilities (KSAs). A 2015 survey of agricultural retailers examined the minimum educational requirements retailers were seeking in their hires, along with the importance of a list of KSAs for the various positions that they customarily fill. The positions included equipment operators, sales specialists, technical support, and agronomists. The KSAs included specifics, such as the ability to install, calibrate, troubleshoot, and repair equipment; knowledge of precision agriculture software; and also more broad skills such as effective written and verbal communication and in making agronomy recommendations. As expected, retailers expressed different educational minimums and different levels of importance for various positions. Overwhelmingly, the retailers indicated difficulty in finding qualified candidates and a predominance of candidates with low or deficient proficiency in areas they rated important. The survey was accomplished using email lists from both CropLife and the Certified Crop Adviser program.

Core Ideas

- Needed skills are changing for agriculturalists working in precision farming.
- It is often difficult for agribusiness to find qualified candidates to fill positions.
- Different sets of skills are needed for equipment operators, agronomists, equipment technicians, technical support, and sales positions.

The adoption of precision farming technologies and the extraction of their value are dependent on farmers and their service providers and advisers having knowledge about the technologies and in having qualified and competent support. Anecdotal evidence suggests that farmers often lack the knowledge or time to fully capitalize on precision farming, and service providers struggle to find competent individuals to fill their sales, service, and support roles. Universities and community colleges struggle to provide the educational structure necessary to maximize student access to classes that focus on precision agriculture. The most widely adopted precision practices have been automated systems related to equipment steering and precise input application, such as autoguidance and section controllers. Once installed, these systems are relatively easy for farmers and their supporting agribusinesses to operate and to benefit from. But a more information-intensive set of technologies that is less automated and more knowledge-based will require a higher level of human capability to maximize benefits. All of the parameters that lead to yield—such as soil, weather, genetics, nutrient management, and pests/crop protection—must be characterized both spatially and temporally, interpreted, and then managed accordingly.

The importance of developing the agricultural workforce has been highlighted in: (1) the PCAST report to the President on the Agricultural Preparedness and the Agricultural Research Enterprise (PCAST, 2012); (2) informal surveys of agricultural employers; (3) an online survey of 86 South Dakota farmers; (4) a published survey of agricultural retailers from across the United States (Erickson and Widmar, 2015); (5) focus group meetings in 2013 by the American Society of Agronomy (ASA) Precision Agricultural Systems community, the ASA–Soil Science Society of America–Crop Science Society of America book committee, the South Dakota State University College of Agriculture and Biological Sciences, and the Agricultural Interactive Distance Education Alliance (AG*IDEA), an affiliate of The Great Plains IDEA; and (6) published articles where educational needs were outlined (Kitchen et al., 2002).

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The findings from these activities reveal that: (1) employers need fully trained precision agronomists and engineers; (2) universities and community colleges are struggling to keep up with providing the needed education due to a lack of competent instructors and effective curricula; (3) different employee skill sets are needed for agricultural retail stores as compared with large agricultural manufacturing companies, (4) students are confused by the wide range of programs marketed under "precision farming"; and (5) regional coordination and effective curricula are needed.

Part of the reasons for these challenges is that precision farming technologies are in a rapid state of change, and that adopting one technology can depend on the adoption of others, or in causing fundamental changes in how a farm or retail agribusiness operates. Most precision farming technology innovation occurs in agribusiness settings and not in universities and community colleges. It is difficult for educators working at a university or community college to stay abreast of innovations, considering their workloads in teaching, research, and extension.

Higher education institutions are gradually, but disjointedly, putting together programs and curricula that educate students for these opportunities. For example AG*IDEA started building a precision certification program, and South Dakota State University independently created a new precision farming major. Both programs are in the process of identifying desired student outcomes and curricula to meet those goals.

The purpose of this survey is to use industry feedback to help guide the developers of future precision agriculture education—to assess current levels of education in the field; what education will be needed in the future for various roles; and to evaluate the knowledge, skills, and abilities needed for professionals working in precision agriculture.

METHODS

Work Roles

With input from industry, we identified five common precision agriculture positions that an agricultural retailer might staff. These include:

- Equipment operator. Operates the equipment that applies pesticides and fertilizers to farmer's fields.
- Agronomist. Provides recommendations on crop and soil management to farmers.
- Precision equipment technician. Installs new precision equipment on implements; troubleshoots and repairs precision equipment on the farm.
- Technical support. Works from dealer or company location via telephone, text, or web interface with farmer customers to troubleshoot precision equipment and software.
- Precision sales specialist. Works specifically with precision equipment sales and support.
- Other. (survey respondent to fill in)

Knowledge, Skills, and Abilities

We identified 10 critical areas of knowledge, skills, or abilities (KSAs) needed by those working in precision agriculture. These are KSAs that might apply more to some roles or less to others from those listed above. But to keep the survey as straightforward as possible, we asked about each of these KSAs for each of the positions.

Survey Administration

The survey was administered electronically via email and a survey link in mid-July 2015. Two email lists were used: one from CropLife magazine (Meister Media Worldwide, 2018), and another from the Certified Crop Adviser program, administered by ASA. Each list comprised approximately 10,000 email addresses. Due to the sources of the lists, the survey results are likely more reflective of crop protection, seed, and fertilizer retailers and consultants as opposed to others that may be offering precision services such as farm equipment dealers, farmers, or farm managers. The Human Research Protection Program Institutional Review Board (IRB) determined that the survey met the criteria for exemption under 45 CFR 46.101(b)(2) IRB Protocol no. 1506016166. There were 171 respondents.

Survey Instrument

See a document version of the survey instrument in the Appendix. As previously noted, the survey instrument used was formatted for electronic delivery.

RESULTS

Number of Employees and Roles

The retail locations surveyed were generally small operations—53% of the retail locations that responded to the survey had 10 or fewer total employees, 28% had 11 to 20 employees, and 15% had 21 to 50 employees, with the remaining reporting more than 50. Overall, 35% of the employees at these locations were working specifically with precision agriculture practices offered by the retailer, with 27% of the employees working full-time on precision and 8% working part-time.

The distribution of precision work roles (full-time and part-time) over all respondents was:

- 28% Equipment operator
- 32% Agronomist
- 12% Precision equipment technician
- 8% Technical support
- 11% Precision sales specialist
- 9% Other. Survey respondents mentioned personnel for soil sampling, fertilizer/pesticide/seed treatment mixing, data analysts, truck drivers, and accounting.

Existing and Future Education Requirements

Survey respondents indicated the current level of education for each of their employee roles at their location, and what they thought should be the required minimum education level in the future, 5 years out.

For equipment operators, a role that is more about completing tasks vs. formulating solutions or interacting with customers, most currently have a high school diploma, and 68% of respondents indicated that level of education was sufficient going into the future (Fig. 1). Nineteen percent of respondents felt a 2-year degree was the minimum education level, and 9% indicated the minimum was a bachelor's degree. Comparing the two graphics indicates that some current equipment operators may be considered over-qualified by their employers with bachelor's or master's degrees.

Most agronomists represented by the survey currently hold bachelor's degrees, and that level of education was indicated as the future standard, with 71% of respondents,
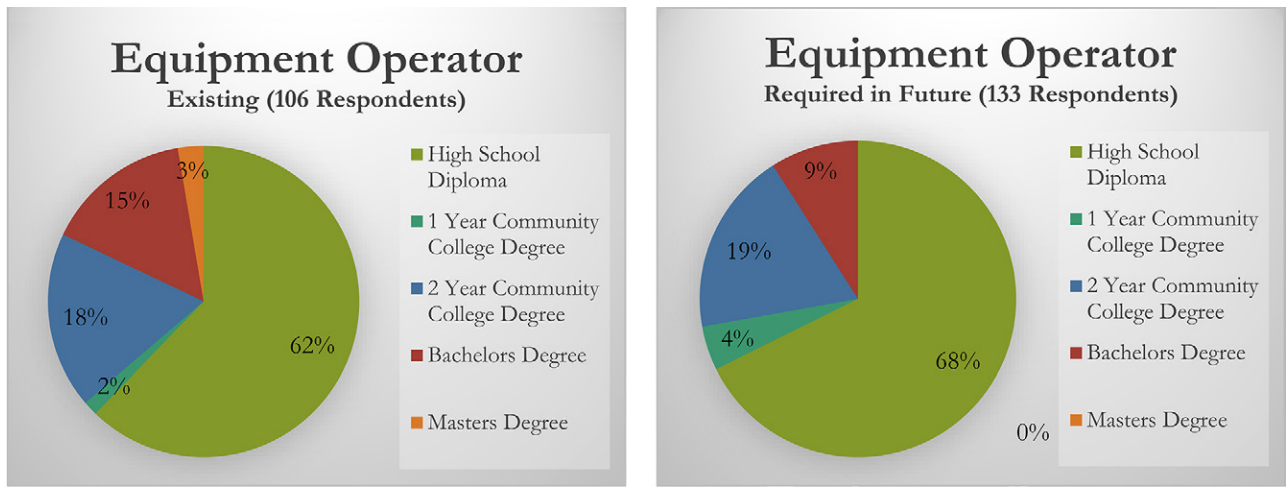
Fig. 1. Existing and future education requirements for equipment operators.
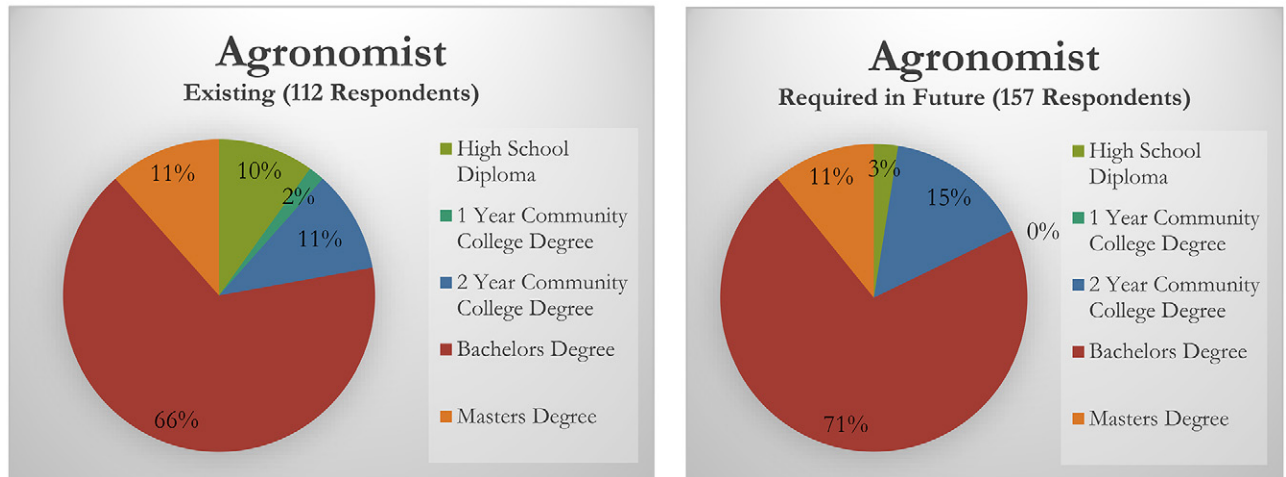

Fig. 2. Existing and future education requirements for agronomists working in precision agriculture.
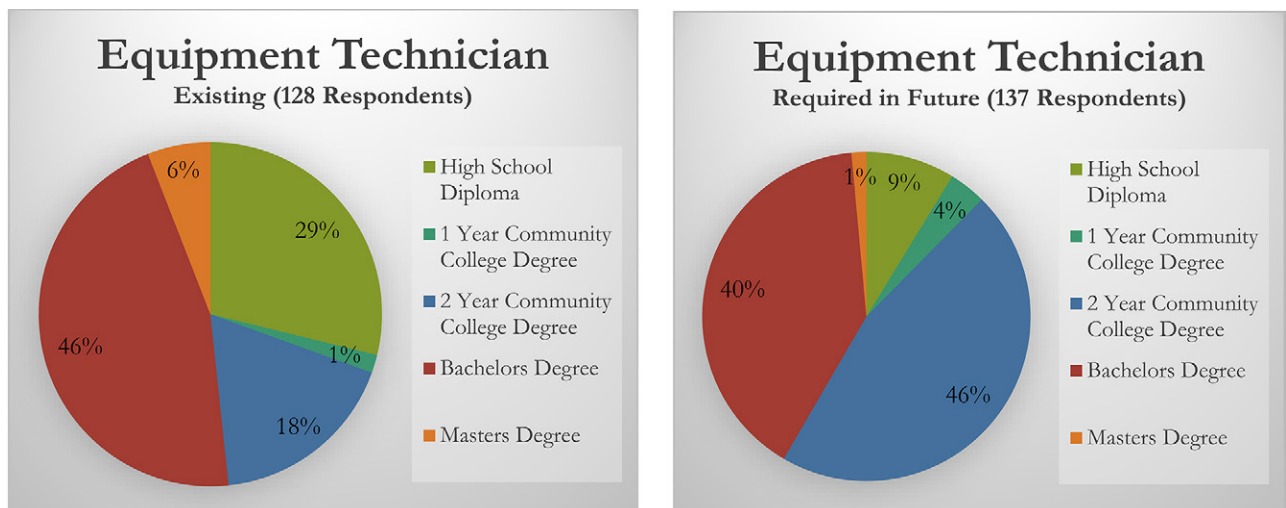

Fig. 3. Existing and future education requirements for precision equipment technicians.
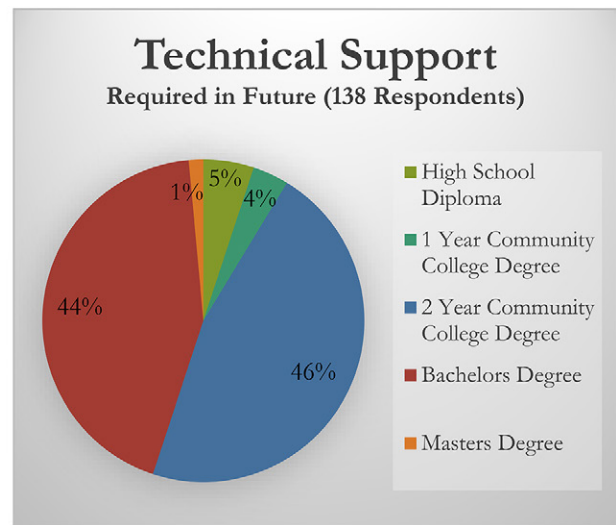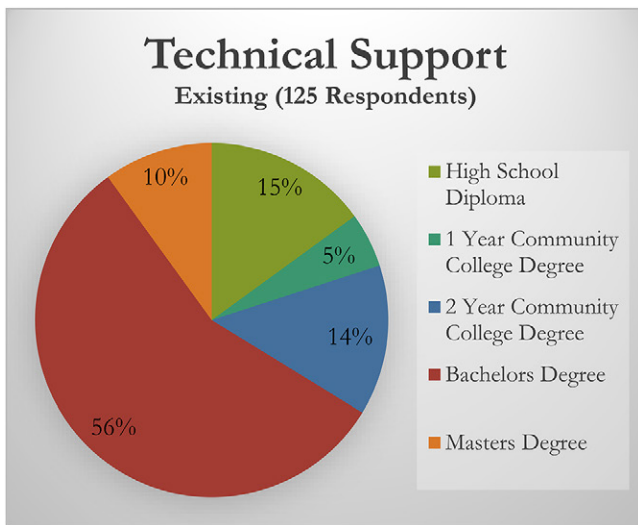
Fig. 4. Existing and future education requirements for precision technical support.
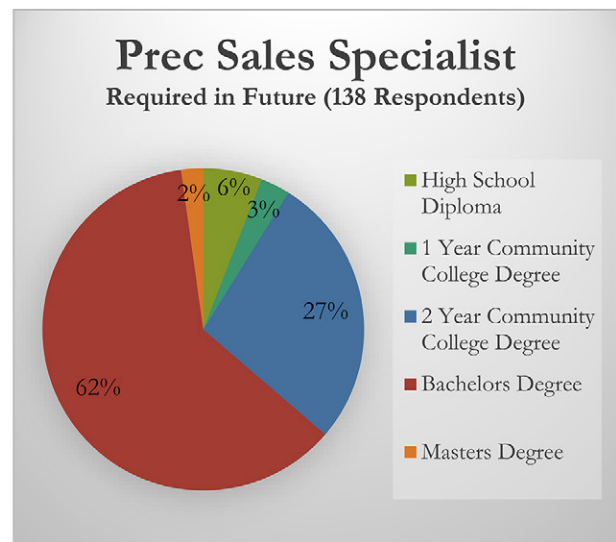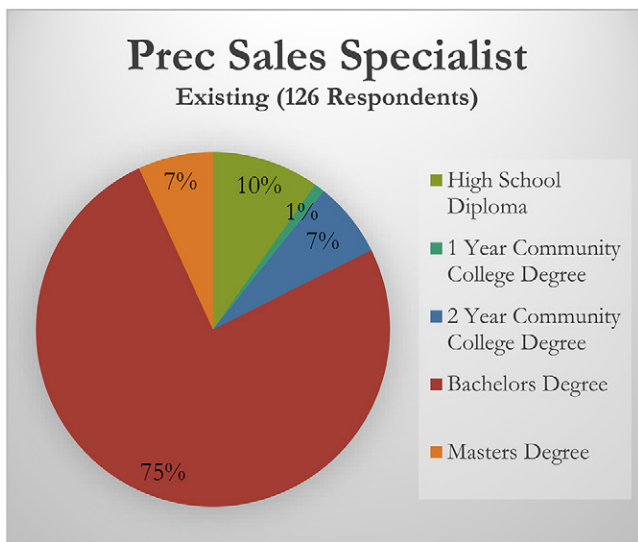

Fig. 5. Existing and future education requirements for precision sales specialists.

although 11% indicated that a master's degree was the minimum and 15% indicated an associate's degree was sufficient (Fig. 2). Currently 10% of precision agronomists have high school diplomas, yet only 3% of respondents indicated this was sufficient for the future.

For precision equipment technicians, currently most have a high school diploma or a bachelor's degree, yet in the future a 2-year degree or a bachelor's degree is indicated as the minimum requirement (Fig. 3). An equipment technician has very specific tasks to complete, and probably more defined than some of the other roles.

For technical support, most employees represented in the survey currently have bachelor's degrees, but in the future the survey indicated that an associate's degree will be an acceptable minimum level (Fig. 4). Currently many tech support employees have master's degrees, but retailers put little value on that additional degree.

For precision sales specialists, currently most have a bachelor's degree, and most respondents indicated that is the desired level of education in the future, although about 25% of retailers thought an associate's degree is sufficient (Fig. 5).

Salaries

Annual salaries retailers expected to pay for precision employees ranged from US$35,000 to $60,000, varying by position and education (Fig. 6). For those with associate's degrees the salary range is $40,000 to 46,000. The annual salary for precision agriculture employees with a bachelor's degree ranges from about $42,000 to $52,000. There is a salary advantage for all positions for having a degree beyond a high school diploma, with the exception of a 1-year degree from a community college. The greatest education advantage is for the role of agronomist, the second greatest for the precision sales specialist, and the least education advantage is for an equipment operator. Going beyond a bachelor's degree to a master's degree resulted in a substantial pay increase only for the agronomist role. The salary numbers did not include benefits such as health insurance or retirement.
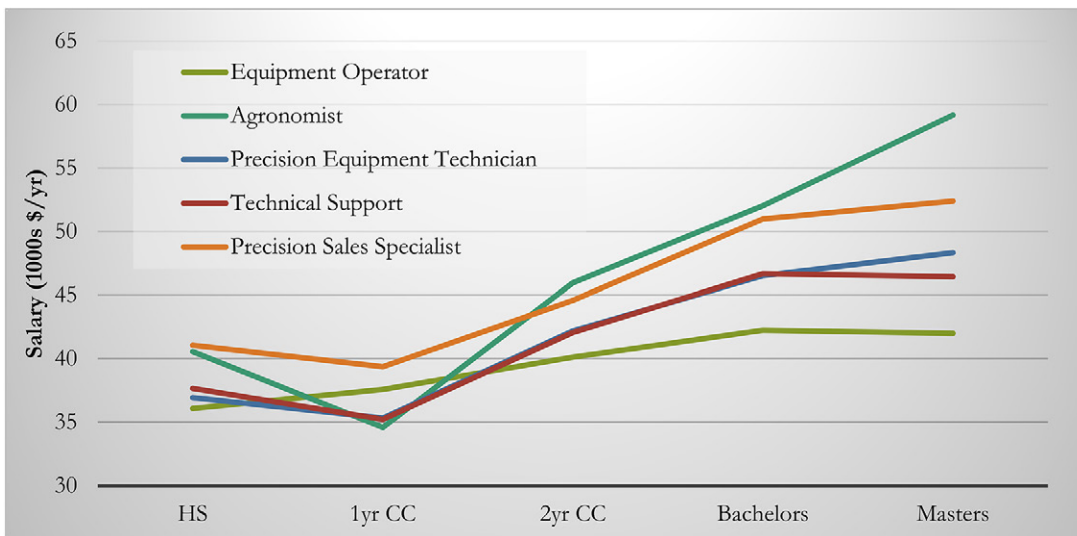
Fig. 6. Annual base salary by work role and level of education.

Difficulty of Locating Qualified Applicants

Respondents overwhelmingly indicated at least some difficulty filling precision positions, with most respondents indicating at least 60 days to fill each of the five roles (Fig. 7). One-third or more of survey respondents indicated that it took more than 90 days to fill each of five roles, with the exception of an equipment operator.

Knowledge, Skills, and Abilities of Interviewees

As another measure of the workforce, we asked retailers to evaluate the KSAs of their prospective employees from their recent interviews of applicants for all precision agriculture positions (Fig. 8). With one exception, most respondents indicated their interviewees were either low or deficient in each of the 10 KSA areas. Interviewees had the highest proficiency for their ability to operate precision agriculture equipment (monitors, controllers, etc.). The lowest proficiency level indicated was for their working

understanding of statistical standards to produce means and standard deviations. These differences may reflect today's current precision technologies, where automation is becoming standard but many have not yet moved to more data-intensive thinking.

Employee Turnover/Hiring Plans

Employee turnover was not a problem for most respondents. Forty-nine percent of retailers indicated no turnover, and 36% had turnover but with little impact on their business. Fifteen percent indicated that turnover had a significant impact on their business. Forty-three percent of respondents indicated they will make precision agriculture hires in the coming year. Overall, this indicates a relatively stable labor situation.
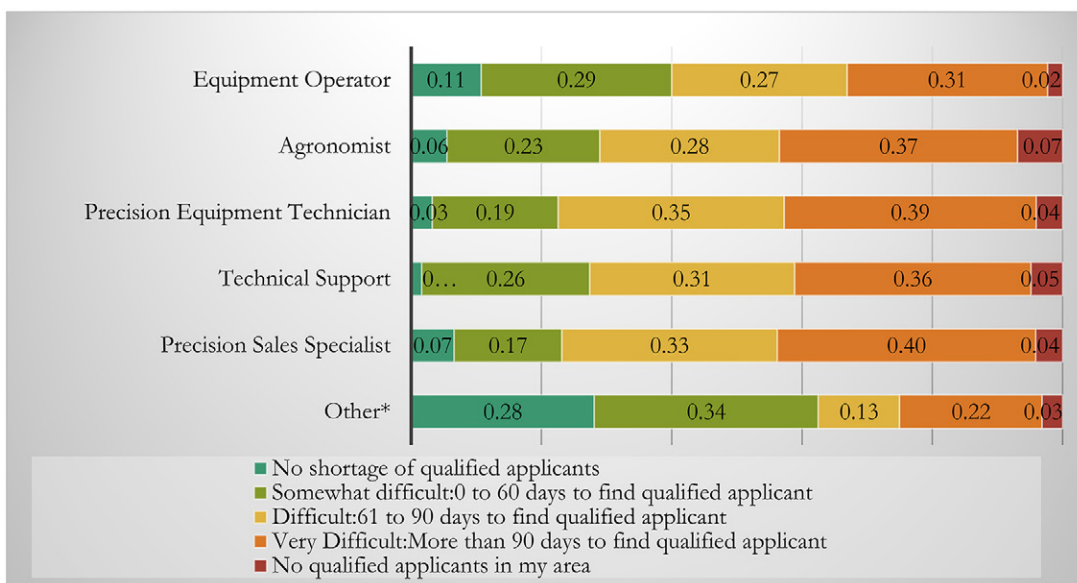

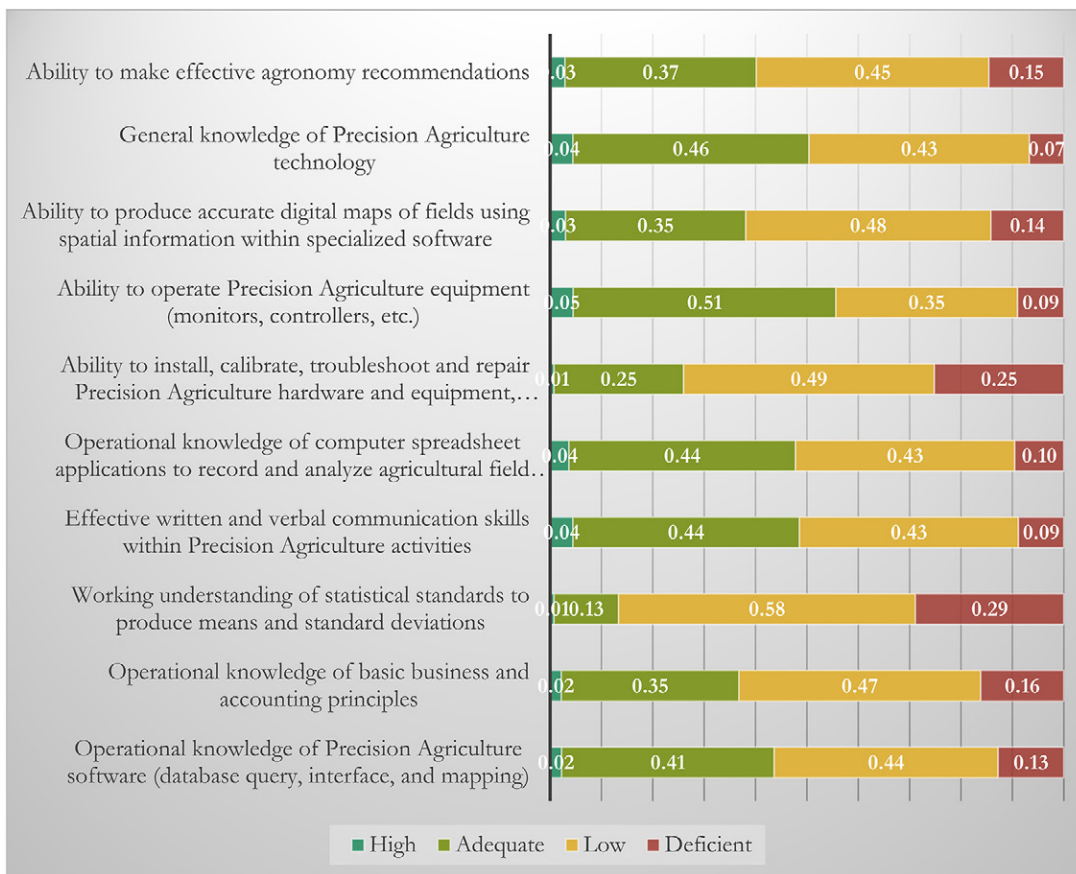Fig. 7. Difficulty of locating qualified candidates.

Fig. 8. Proficiency level of interviewees.

Importance of Knowledge, Skills, and Abilities

Survey respondents evaluated a set of 10 KSAs related to precision farming for the five work roles (Fig. 9). As expected, the importance of these proficiencies ranked the lowest for an equipment operator, with the exception of being able to operate or install, calibrate, and repair precision agriculture equipment. Overall, the highest-rated KSAs among all positions, other than equipment operators, was a general knowledge of precision agriculture technology and abilities related to verbal and written communication. The lowest overall rating was for an ability to make effective agronomy recommendations, except for the agronomist. For the agronomist, this ability had the highest importance of any individual work role.

Satisfaction with and Preference for Precision Training

Survey respondents were generally satisfied with the precision agriculture training they received from companies. Sixty-eight percent of respondents indicated that they received training from the companies providing precision hardware or software. Survey respondents rated precision equipment training as follows: 15% inadequate, 39% adequate, 38% good, and 5% excellent. Survey respondents rated software training as follows: 19% inadequate, 41% adequate, 32% good, and 8% excellent.

Regarding how to provide education, 57% preferred that it be administered face-to-face in a classroom, 20% preferred internet, and 23% were not interested in paying for training. The ideal length of training was 2 days. January is

the best month, followed by February, December, November, August, and July. As an average, respondents considered that $157 was a reasonable cost for an 8-hour day of classroom training. This cost is similar to in-state tuition rates at a land-grant university, and may not accurately reflect the market, as what a retailer considers a reasonable cost might be quite different than what they might actually pay. The range of responses for classroom training was $0 to $1000.

DISCUSSION

The survey results show that precision workers generally have a diploma or degree that meets or exceeds the expectations of their employers. However, it has been hard to find qualified applicants, and the precision agriculture proficiencies of those candidates interviewed are mostly low or deficient. This possibly indicates a mismatch of degree and the ability to perform satisfactorily in a position. Except for equipment operators, effective written and verbal communication skills and a general knowledge of precision technologies were the KSAs retailers most valued in their precision workers.

Most of the precision workforce has a bachelor's (4-year) degree, with the exception of equipment operators. Most equipment operators currently have a high school diploma, and retailers indicate that this will be sufficient in the future. For agronomists and precision sales specialists, survey respondents indicated that a bachelor's level of education will be the minimum in the future for these positions. And although most current equipment technicians and tech support personnel also have bachelor's degrees, retailers were split on the need for that degree, with a slightly higher
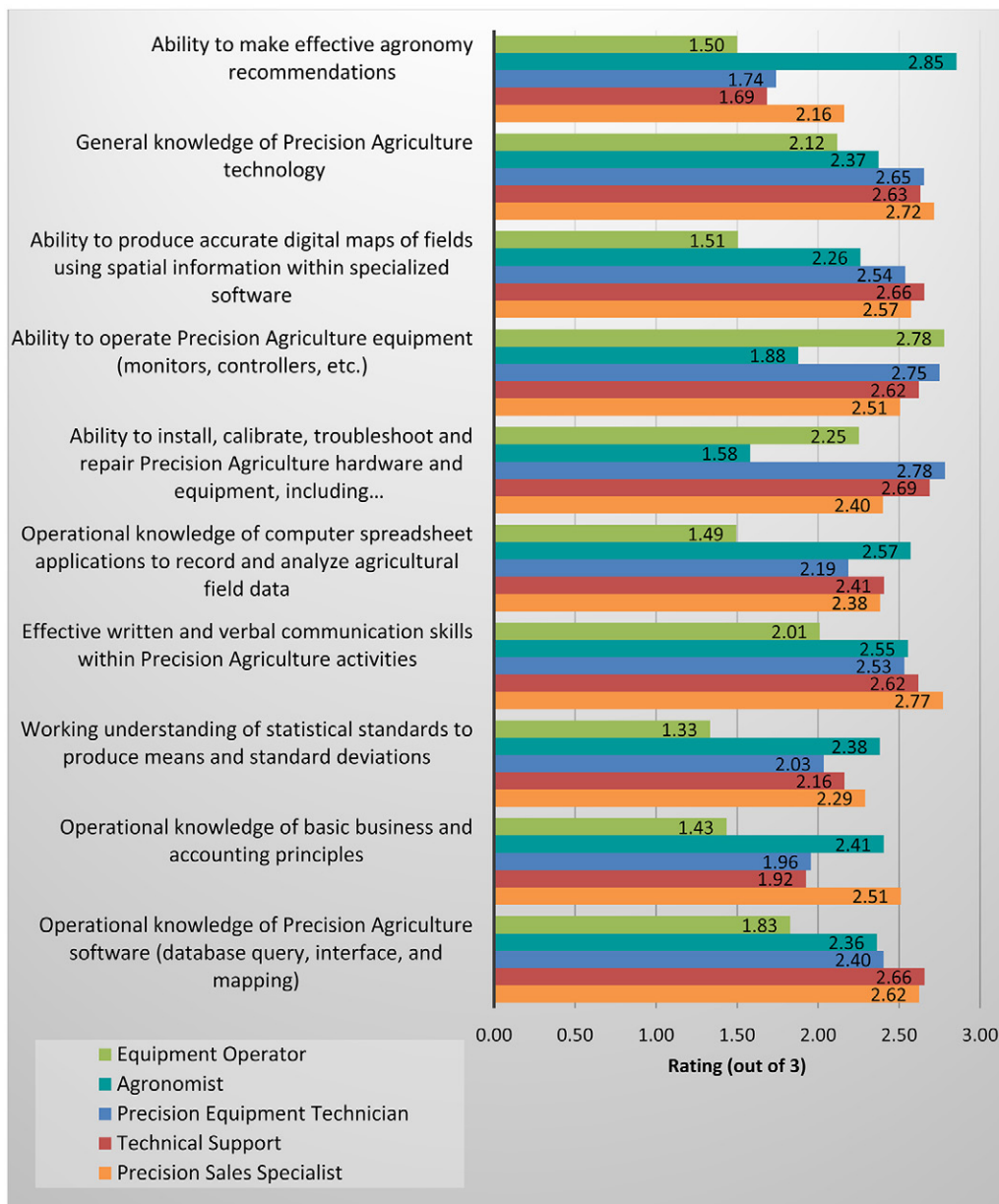
Fig. 9. Importance of knowledge, skills, and abilities (KSAs) for various work roles (1 = lowest importance; 3 = highest).

percentage of respondents indicating that an associate's (2-year) degree was the required educational level.

The results from a complementary survey of university and community college educators (Fausti et al., 2018) suggests that 1- and 2-year post high school educational institutions may have a competitive advantage in training students for entry into certain positions in retail precision agriculture. This may be because preparation from a 2-year institution could be more practical and field-applied vs. the more theoretical approach often used by many 4-year institutions. Also, with an overall lack of confidence in the proficiencies of their hires, retailers may have decided that they or their affiliate companies will necessarily take on the responsibility of providing training of new employees—so why make the often more expensive investment in a bachelor's degree holder? Given that there is a shortage of qualified applicants for precision agriculture openings, 1- and 2-year programs can produce potential employees faster than 4-year institutions. Therefore, the challenge to bachelor's

degree–granting institutions is in developing the curriculum necessary to produce the type of employee to meet the needs of the retail industry.

In a related question regarding education, retailers expect to pay a higher salary for workers earning bachelor's degrees as compared with high school diplomas or associate's degrees, but master's degrees held a premium price only for an agronomist.

Retailers indicate an acute need for precision agriculture education. One indication of this is the overall difficulty in finding qualified candidates for precision agriculture positions. For the five positions defined, most retailers overall thought finding qualified candidates was at least difficult (at least 60 days to fill a position), and with the exception of equipment operators, more than one-third of respondents said filling any of the other four positions was very difficult (at least 90 days to fill a position).

Another indication of the need for precision agriculture education is the proficiency level of interviewees. We defined

10 KSAs that should be central to those working in precision agriculture. With the exception of one, most respondents indicated their interviewees were either low or deficient in each of the 10 KSAs. Interviewees had the highest levels for their ability to operate precision agriculture equipment (monitors, controllers, etc.). The lowest proficiency level indicated was for their working understanding of statistical standards to produce means and standard deviations.

The differences between the current performances of employees/prospective employees and the desired performance indicated by the retailers should provide the focus for future education offerings. Outside of equipment operators, retailers rated knowledge of precision agriculture technology and abilities related to verbal and written communication as most important. These two KSAs were among the higher-rated of prospective employees, although most were still low or deficient in candidates interviewed. A working understanding of statistical standards to produce means and standard deviations, as well as the ability to install, calibrate, troubleshoot, and repair precision agriculture hardware and equipment were the two proficiencies most deficient in applicants, but not among those most highly rated as important by retailers.

Retailers generally are pleased with the training they receive from companies. They greatly prefer classroom training vs. internet-based, and they consider about $20 per hour a reasonable cost.

APPENDIX

South Dakota State University, Purdue University

PLEASE HELP EDUCATORS BETTER PREPARE YOUR EMPLOYEES TO WORK IN PRECISION AGRICULTURE!

Please fill out and return this brief survey. **PLEASE RETURN BY JULY 10, 2015.**

Thanks again for your participation.

If you cannot provide complete answers to questions, please do provide information to the best of your knowledge and resources.

If you run into any difficulties please contact Scott or Bruce for review at the email addresses provided in the email.

1. Zip code of your business location: _____.
2. Total number of employees at this location: _____.
3. Employees working directly with precision ag at this location: Full time _____. Part time _____.
4. List the number of each employee roles at your location in the Total column, full-time and part-time. Then, indicate the number holding each of the diplomas/degrees listed.

	Total Number	High School Diploma	1-Year Community College Degree	2-Year Community College Degree	Bachelor's Degree	Master's Degree
		Sum of each row should equal left column				
Equipment Operator Runs the equipment that applies pesticides and fertilizers to farmer's fields	____	____	____	____	____	____
Agronomist Provides recommendations on crop and soil management to farmers	____	____	____	____	____	____
Precision Equipment Technician Installs new precision equipment on implements; troubleshoots and repairs precision equipment ON SITE	____	____	____	____	____	____
Technical Support Works REMOTELY with farmer customers to troubleshoot precision equipment and software	____	____	____	____	____	____
Precision Sales Specialist Works specifically with precision equipment sales and support	____	____	____	____	____	____
Other (list) _____	____	____	____	____	____	____

5. In five years, what will be the required educational level for employment for each of the employee types? Leave blank any option that does not apply to your business. Place only one checkmark in each row.

	High School Diploma	1-Year Community College Degree	2-Year Community College Degree	Bachelor's Degree	Master's Degree
	Check one box per row				
Equipment Operator	☐	☐	☐	☐	☐
Agronomist	☐	☐	☐	☐	☐
Precision Equipment Technician	☐	☐	☐	☐	☐
Technical Support	☐	☐	☐	☐	☐
Precision Sales Specialist	☐	☐	☐	☐	☐
Other (list) _____	☐	☐	☐	☐	☐

6. What salary do you expect to pay a new employee for the positions and levels of education listed? Leave blank any option that does not apply to your business.

	High School Diploma	1-Year Community College Degree	2-Year Community College Degree	Bachelor's Degree	Master's Degree
	Base salary, $/year, not including benefits (i.e., for $36,000 write 36k)				
Equipment Operator	____	____	____	____	____
Agronomist	____	____	____	____	____
Precision Equipment Technician	____	____	____	____	____
Technical Support	____	____	____	____	____
Precision Sales Specialist	____	____	____	____	____
Other (list) _____	____	____	____	____	____

7. Please indicate the level of difficulty finding qualified applicants in the precision ag employee types listed below. Place only one checkmark in each row.

	No shortage of qualified applicants	Somewhat difficult: 30 to 60 days to find qualified applicant	Difficult: 60 to 90 days to find qualified applicant	Very Difficult: More than 90 days to find qualified applicant	No qualified applicants in my area
	Check one box per row				
Equipment Operator	☐	☐	☐	☐	☐
Agronomist	☐	☐	☐	☐	☐
Precision Equipment Technician	☐	☐	☐	☐	☐
Technical Support	☐	☐	☐	☐	☐
Precision Sales Specialist	☐	☐	☐	☐	☐
Other (list) _____	☐	☐	☐	☐	☐

8. Rate the level of knowledge of individuals that you have interviewed for precision positions in the last two years. Place one checkmark per row.

	Deficient	Low	Adequate	High
	Check one box per row			
Ability to make effective agronomy recommendations	☐	☐	☐	☐
General knowledge of Precision Agriculture technology	☐	☐	☐	☐
Ability to produce accurate digital maps of fields using spatial information within specialized software	☐	☐	☐	☐
Ability to operate Precision Agriculture equipment (monitors, controllers, etc.)	☐	☐	☐	☐
Ability to install, calibrate, troubleshoot and repair Precision Agriculture hardware and equipment, including electrical/mechanical/hydraulic/software systems	☐	☐	☐	☐
Operational knowledge of computer spreadsheet applications to record and analyze agricultural field data	☐	☐	☐	☐
Effective written and verbal communication skills within Precision Agriculture activities	☐	☐	☐	☐
Working understanding of statistical standards to produce means and standard deviations	☐	☐	☐	☐
Operational knowledge of basic business and accounting principles	☐	☐	☐	☐
Operational knowledge of Precision Agriculture software (database query, interface, and mapping)	☐	☐	☐	☐

9. When screening potential new employees to fill an opening on your precision ag team in the areas listed, how important are the following skill and knowledge areas? Please rank each knowledge area from 1 to 3. With 1 being the most important and 3 being the least important. Please provide a rank in each box.

	Equipment Operator	Agronomist	Prec Equipment Technician	Technical Support	Prec Sales Specialist
	1 = most important, 3 = least important				
Ability to make effective agronomy recommendations	___	___	___	___	___
General knowledge of Precision Agriculture technology	___	___	___	___	___
Ability to produce accurate digital maps of fields using spatial information within specialized software	___	___	___	___	___
Ability to operate Precision Agriculture equipment (monitors, controllers, etc.)	___	___	___	___	___
Ability to install, calibrate, troubleshoot and repair Precision Agriculture hardware and equipment, including electrical/mechanical/hydraulic/software systems	___	___	___	___	___
Operational knowledge of computer spreadsheet applications to record and analyze agricultural field data	___	___	___	___	___
Effective written and verbal communication skills within Precision Agriculture activities	___	___	___	___	___
Working understanding of statistical standards to produce means and standard deviations	___	___	___	___	___
Operational knowledge of basic business and accounting principles	___	___	___	___	___
Operational knowledge of Precision Agriculture software (database query, interface, and mapping)	___	___	___	___	___

10. Do you plan to hire a precision ag employee(s) in the next year? Yes ___   No ___

How has precision ag employee turnover impacted your business in the last two years?
- ☐ no turnover
- ☐ turnover but with little impact on my business operations
- ☐ turnover with significant impact on my business operations

11. Does your dealership receive precision ag training from the manufacturers you purchase precision ag equipment and/or software?
Yes ___   No ___

If Yes, please answer the question below:

I consider the quality of the precision ag training provided by the manufacturer to be:

	Incomplete	Adequate	Good	Excellent
Software training	☐	☐	☐	☐
Equipment training	☐	☐	☐	☐

12. Which method would you prefer to have your employees participate in a fee based training program?
- ☐ Classroom setting
- ☐ Internet setting
- ☐ Not interested in fee based training

13. If a classroom option were available, how many days should the training program be scheduled to minimize interruption to your business? _____ days

14. Which month of the year is best for classroom training to be scheduled? _____ month

15. What do you believe would be a reasonable per day cost (8 hours) of a classroom based training program? _____ $/day

16. What do you believe would be a reasonable cost of an internet-based training program? $ _____

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About the corresponding author...

Bruce Erickson is the agronomy distance and outreach director at Purdue University. He developed the Agronomy e-Learning Academy, which has served more than 1100 students from 22 countries and 39 states through its three courses: Agronomy Essentials, Precision Agriculture, and Nutrient Management. He is the agricultural lead for the Wabash Heartland Innovation Network project, aiming to develop new applications and promote the adoption of digital agriculture and advanced manufacturing. Erickson's research centers on precision farming economics and adoption, where he leads the CropLife/Purdue Precision Dealer Survey, the most complete and longest-running measure of precision agriculture technology adoption. He started his career as an agronomist with DuPont Pioneer in Iowa, served as senior technical designer at Agri Business Group in Indianapolis, managed Purdue's Site-Specific Management Center and Top Farmer Crop Workshop, then was the agronomy education manager for the American Society of Agronomy (ASA). At ASA he taught several online courses and was responsible for the International Certified Crop Adviser (CCA) exam, the minimum qualifying exam for the 10,000+ member Certified Crop Adviser program. Erickson received the 2018 Educator/Researcher Award of Excellence from the PrecisionAg Institute.

Purdue University is Indiana's land-grant institution with research, teaching, and extension at its core. Its engineering, aviation, and agricultural programs are highly ranked and recognized worldwide. The West Lafayette campus is home to about 30,000 undergraduate students, 10,000 graduate students, and 3000 faculty and staff. The College of Agriculture is ranked ninth in the world by QS World University Rankings, and has about 2700 undergraduate students in agricultural and biological engineering, agricultural economics, agronomy, animal sciences, biochemistry, botany and plant pathology, entomology, food science, forestry, and horticulture and landscape architecture.