Exploring the Educational Landscape of Precision Agriculture Workforce Development

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Introduction/Literature Review/Need for Study

Technological innovation is reshaping industries worldwide, with precision agriculture (PA) emerging as a key driver in modern agriculture (Rose & Chilvers, 2018). PA integrates technologies that help farmers optimize inputs, improve profitability, and manage resources sustainably (Gebbers & Adamchuk, 2010). These systems rely on decision-support technologies that require skilled operators to translate data into practice, addressing economic and environmental challenges (Laveglia et al., 2024). Despite its potential, awareness and adoption of PA among educators and students remain limited, and employers report shortages of graduates with essential technical competencies (McFadden et al., 2023). Educators recognize PA's importance but face barriers, including limited professional development, inadequate curriculum support, and restricted access to equipment (Stwalley & Tormoehlen, 2024). Human Capital Theory (Schultz, 1961) emphasizes educational investment to meet workforce demands, highlighting the need for early exposure at the secondary level.

Theoretical Framework

Human Capital Theory (HCT) positions education and training as investments that strengthen individual productivity and economic outcomes. Schultz (1961) framed education as human capital, while Becker (1993) distinguished between general and specific human capital. PA requires both forms of capital, as technologies like sensors and geospatial analytics demand transferable competencies alongside specialized technical knowledge (King et al., 2019). However, the shortage of PA-skilled workers reflects underinvestment in human capital and underscores the importance of stronger workforce development through education and training, while current professional development and student exposure often promote short-term awareness rather than sustained competency (Lawver et al., 2024).

Methodology

This study used content analysis to examine peer-reviewed journal articles and publicly available curricula on precision agriculture (PA) education in high school classrooms (Gough et al., 2017; Krippendorff, 2004). An unobtrusive research design guided the analysis of scholarly articles. A systematic scoping review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Page et al., 2021). Studies were included if they were U.S.-based, involved high school students, used PA technologies, reported instructional implementation, and were published within the past decade. The databases searched were Education Research Complete, CAB Abstracts, and Web of Science. The search produced 2,501 records across many agricultural disciplines, but very few addressed high school instruction. After applying the inclusion and exclusion criteria, only nine articles met the requirements. Most articles that focused on technology and industry rather than students and education were therefore excluded from the review.

Purpose/Objectives

This study examined existing literature and curricula to evaluate educator and student readiness for PA workforce development, with the following objectives:

1. Explore the current state of K–12 precision agriculture classroom research
2. Examine how publicly available PA lesson plans contribute to building students' knowledge, skills, and career awareness as a form of human workforce development.

Results/Findings

The scoping review revealed a limited but emerging body of research on precision agriculture (PA) education in high school classrooms. Across the nine peer-reviewed studies, educators valued PA technologies but reported low confidence and limited instructional capacity due to barriers such as insufficient training, lack of curriculum alignment, restricted instructional time, and limited access to equipment. Although teachers expressed strong interest in PA technologies, instructional approaches largely remained traditional. Student-focused interventions demonstrated consistent gains in knowledge, STEM confidence, career interest, and readiness when experiential learning strategies were employed; however, most studies relied on short-term assessments, limiting insight into sustained learning or long-term workforce readiness. For objective two, six PA-related programs were identified, and two were standards-based; most lacked alignment with workforce competencies or established agricultural education frameworks, and experiential components were common.

The findings further indicated substantial variation in the depth and structure of PA instruction across studies and curricula. Many learning experiences were delivered as isolated workshops or short, project-based lessons, providing exposure but not fostering durable competencies. Access to tools such as drones, GIS, and sensors differed widely, creating uneven opportunities for skill development. Curricular materials also varied in clarity, accessibility, and instructional structure, producing a fragmented instructional landscape shaped by local resources and program design.

Discussion/Conclusions

PA education at the secondary level remains limited and uneven, with few studies examining classroom implementation and persistent barriers constraining teacher capacity (Smalley et al., 2019). Although educators recognize PA's relevance, gaps in professional development, curriculum support, and access to technology continue to restrict meaningful integration (Stwalley & Tormoehlen, 2024). Student interventions show short-term gains but lack sustained competency development. Publicly available curricula mirror these inconsistencies, with limited alignment to standards and variable depth. These patterns reflect systemic underinvestment in both teacher and student skill development (Becker, 1993; Schultz, 1961). Strengthening the PA workforce preparation will require coordinated, long-term investment to transform early exposure into durable human capital. Teachers frequently express strong interest in PA tools such as drones and variable rate technologies, yet many still lack the confidence and instructional resources needed to teach them effectively (Akwah et al., 2024). The uneven quality and accessibility of available curricula further widen disparities in student learning opportunities and limit the scalability of PA workforce preparation.

Implications/Recommendations

The findings suggest that PA workforce development at the secondary level remains limited and unevenly implemented. While educators and students recognize the value of PA technologies, persistent barriers often prevent sustained integration and lead to a prioritization of exposure over meaningful skill development. From a Human Capital Theory perspective, professional development alone is unlikely to support long-term PA integration. Strengthening workforce preparation will require standards-based, SBAE-aligned curricula, consistent instructional support such as communities of practice and shared teaching resources, and partnerships that expand student access to equipment, data, and experiential learning opportunities. These structural investments emphasize durable skills development over short-term exposure and increase the likelihood that students graduate with workforce-relevant PA competencies.

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