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Robotics Workshop for Middle School Teachers of Agriculture-Related Subjects

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Robotics Workshop for Middle School Teachers of Agriculture-Related Subjects

Abstract

Workshops are an integral part of professional development activities of K-12 STEM teachers. At the same time, the opportunities for workshops are limited. Availability, variety, and timeliness are among many factors that prevent teachers from upgrading their knowledge and skills to keep up with the new technology and put it in the classroom settings. The notion is especially relevant for teachers of agriculture-related subjects. Agriculture has traditionally relied on the experience of the previous generations. The new industrial revolution, Industry 4.0 (I4.0), is rapidly transforming traditional farming and making robotics relevant for new student audiences, including middle schoolers.

A team of STEM graduate students and a K-12 professional proposed, advertised, designed, and ran a workshop to address the needs of middle school teachers of agriculture-related subjects who decide to bring robotics in their classrooms. The team's effort is a voluntary part of their participation in an inaugural eight-week workforce development program at a large Midwestern university in collaboration with other universities around the country. The team based their workshop on the curriculum that they designed during the program. The curriculum included a 11-lesson course in robotics for agriculture for middle school student and a teacher guide.

The results of the team's workshop initiative demonstrated the demand for robotics workshops among K-12 STEM teachers of agriculture-related subjects. The workshop's pre- and post-surveys showed increase in knowledge, skills, and motivation to teach programming among the participants. The described workforce development program created a unique research environment that encouraged the team to generate and implement ideas beyond the required deliverables, such as the presented workshop. Other K-12 STEM teachers can benefit from similar workshops at their local universities.

Keywords: Workshop, Robotics, Programming, Agriculture, Curriculum, K-12, Graduate Students, Workforce Development, STEM, Smart Farming, Industry 4.0 (I4.0)

Introduction

The rapid integration of Industry 4.0 (I4.0) technologies is fundamentally transforming the agricultural sector, creating an urgent need to modernize K-12 STEM education to prepare students for future careers. This convergence of robotics, data science, and traditional agriscience presents a significant challenge for middle school teachers, particularly those of agriculture-related subjects, who often lack the confidence, technical skills, and ready-to-use resources to integrate these advanced concepts into their classrooms. This paper examines a targeted professional development (PD) workshop, "Smart Farming: The Future of Agriculture" for the middle school teachers, which was designed and implemented by a university-K-12 partnership as a part of the AgBridge program (Kuleshov & Zhang, 2026), a mentorship and curriculum co-creation effort within the National Science Foundation (NSF) Engineering Research Center (ERC) Internet of Things for Precision Agriculture (IoT4Ag), jointly hosted by Purdue Open Ag Technology and Systems (OATS) center and IoT4Ag. The following sections present a literature review establishing the theoretical foundation for proposing the workshop, a detailed description of the workshop's structure and curriculum, an analysis of its outcomes in increasing teacher self-efficacy, and a discussion of the implications for scalable, effective teacher preparation in the era of smart agriculture.

Literature Review

The Imperative for Continuous STEM Teacher Professional Development

The accelerating velocity of technological innovation characterizes the modern STEM landscape, presenting a formidable and continuous challenge for K-12 educators. Their critical role in preparing a future-ready workforce necessitates the mastery of foundational concepts and fluency in emerging domains such as robotics, data science, and automation. Within this context, PD serves as the essential bridge between advancing fields and classroom practice. Workshops, as a focused and intensive PD modality, are particularly significant for delivering hands-on, skill-based training in new technologies. However, the efficacy and accessibility of these workshops are uneven, often failing to address the specific, interdisciplinary needs of teachers in subjects undergoing rapid transformation. This is acutely evident in the convergence of agricultural science and I4.0 technologies. This literature review synthesizes current scholarly discourse on three interrelated themes: the established principles of effective STEM teacher PD, the integration of robotics and computational thinking into middle school curricula, and the urgent need to modernize agricultural education through technological infusion. The literature review emphasizes that the development of scalable, collaborative, and content-specific workshop models is paramount to empower teachers as agents of curricular modernization, ensuring students gain relevant exposure to the technological underpinnings of critical industries.

The Landscape of K-12 STEM Teacher Professional Development and Workshops

The foundation of effective teacher learning is well-documented in educational research. High-quality PD is characterized by features such as content focus, active learning, coherence with school curriculum and policies, sufficient duration (including follow-up support), and collective participation among teachers (Desimone, 2009; Garet et al., 2016). Workshops, by design, can encapsulate these elements, providing a venue for immersive engagement with new pedagogical content knowledge (PCK). For STEM disciplines, where content is inherently dynamic, sustained and subject-specific PD is a prerequisite for maintaining instructional relevance and teacher self-efficacy (National Research Council, 2012). Despite this understanding, a persistent gap exists between ideal PD models and on-the-ground realities. Teachers frequently report that available PD is generic, misaligned with their immediate classroom contexts, or consists of one-off sessions without embedded support for implementation (Darling-Hammond et al., 2017).

This disconnect is exacerbated for training in specialized, high-tech areas where expertise is often siloed within university engineering departments or industry, far removed from the pedagogical realities of the K-12 classroom.

Robotics and Programming in Middle School STEM Education

The challenge is particularly pronounced for the integration of advanced tools like robotics and programming. Effective PD in this arena must address a dual imperative: developing teachers' own technical proficiency while simultaneously fostering their ability to translate that proficiency into developmentally appropriate, engaging student learning experiences (Koehler & Mishra, 2009). This requires moving beyond simple software tutorials to workshops that model the pedagogical strategies suitable for a hands-on, inquiry-based, and often problem-based learning environment. Research indicates that PD is most effective when it is collaborative and involves teachers in the co-creation or adaptation of curriculum materials, thereby increasing ownership and applicability (Penuel et al., 2007). Furthermore, partnerships between K-12 educators and content experts from universities have been identified as a potent model for creating relevant PD. Such collaborations leverage deep content knowledge from higher education while grounding development in authentic classroom needs and constraints, as evidenced by programs that pair graduate students or faculty with practicing teachers (Laursen et al., 2012; Andrews et al., 2020).

The integration of robotics and introductory programming into middle school education has been widely advocated as a means to develop essential 21st-century competencies. Engagement with robotics platforms is shown to promote computational thinking – a problem-solving process involving decomposition, pattern recognition, abstraction, and algorithm design – as well as foster skills in collaboration, perseverance, and systems thinking (Bers et al., 2014; Grover & Pea, 2013). Middle school is recognized as a critical developmental window for capturing and sustaining student interest in STEM pathways, and hands-on, tangible robotics activities can significantly positively influence attitudes, particularly among student demographics historically underrepresented in computer science and engineering fields (Nugent et al., 2016). The pedagogical approach matters; curricula that frame robotics within authentic, meaningful problem contexts, rather than as abstract programming exercises, lead to deeper engagement and learning (Eguchi, 2014).

However, teacher readiness remains the most significant barrier to widespread and effective implementation. Many in-service teachers, including those in general STEM subjects, lack formal training in computer science or engineering, leading to low self-efficacy and confidence in teaching programming concepts and managing a technology-rich, constructionist classroom (Yadav et al., 2017). This creates a direct and pressing demand for PD that is both technically supportive and pedagogically enlightening. Effective models often employ a "teacher-as-learner" approach, where educators firsthand experience the same projects, troubleshooting, and iterative design processes they will later facilitate (Menekse, 2015). Crucially, these workshops must provide more than inspiration; they must supply robust, classroom-ready resources. Teachers are more likely to implement new strategies when PD includes comprehensive, scaffolded curriculum materials, lesson plans, and assessment tools that can be directly adapted to their specific teaching contexts (Shernoff et al., 2017). The provision of such resources reduces the overwhelming burden of curriculum creation from scratch and lowers the barrier to initial implementation.

The Transformation of Agriculture and the Rise of "Agri-tech" Education

The field of agricultural education is undergoing a paradigm shift, moving from a primarily biological and production-oriented discipline to a high-tech, interdisciplinary STEM field. The Fourth Industrial Revolution (I4.0), characterized by cyber-physical systems, the Internet of Things (IoT), Big Data, and automation, is profoundly transforming agri-food systems (Wolfert et al., 2017). Concepts like precision agriculture, which uses sensors and data analytics for resource-efficient farming, and automated systems, from drone scouting to robotic harvesting, are becoming mainstream. This evolution demands a parallel modernization of K-12 agricultural education. To cultivate a workforce capable of driving and sustaining this technological transformation, students must be introduced to the core concepts of mechatronics, sensor technology, data literacy, and systems engineering within the authentic context of food and natural resource management (Lawson et al., 2020; Stone et al., 2022).

Teachers of agricultural science or related STEM subjects (e.g., environmental science, biology with agriscience modules) often possess strong foundations in life sciences but may have limited formal exposure to engineering, robotics, and computer science principles (Huffman & Lawver, 2019). The traditional curriculum and associated PD have not kept pace with industry changes, creating a specific and urgent professional learning gap. This gap is about both access to hardware and the pedagogical content knowledge to effectively integrate that hardware into meaningful instruction. Workshops that successfully bridge this gap do so by contextualizing technology within authentic agricultural challenges. For instance, rather than teaching generic robot navigation, a workshop might focus on programming an autonomous robot to follow a predefined path simulating a planting pattern or using a sensor suite to monitor soil conditions (Thompson et al., 2020). Problem-Based Learning (PBL) approach makes the technology relevant, demonstrates clear career connections, and aligns with the integrative spirit of STEM education by breaking down subject silos.

University-K-12 Partnerships as a Catalyst for Innovative Professional Development

The intersection of the three domains – effective PD, robotics integration, and modernized agricultural education – reveals a critical niche for innovative PD models. University-K-12 partnerships emerge as a particularly promising vehicle for addressing this niche. Universities are reservoirs of advanced technological expertise, research insights, and human capital in the form of faculty and graduate students engaged in cutting-edge work. Collaborations that strategically leverage these assets, while being guided by the pedagogical expertise and practical classroom awareness of K-12 professionals, can generate highly relevant and impactful PD (Laursen et al., 2012).

Graduate students, in particular, can be invaluable partners. Their proximity to emerging research, combined with often-strong technical skills and a desire for broader impacts, makes them ideal conduits for translating advanced concepts into accessible forms (Andrews et al., 2020). PD initiatives co-developed by graduate students and teachers are often marked by innovation, freshness, and a focus on practical applicability, as the partnership naturally balances cutting-edge content with classroom feasibility.
These collaborative models can directly tackle the "timeliness" problem often cited in PD critiques. Traditional textbook and curriculum development cycles are too slow for rapidly evolving fields like robotics and precision agriculture. In contrast, a university-based team can quickly design workshops around new software updates, affordable hardware kits, or contemporary research problems, providing teachers with the most current knowledge and applications. Such partnerships can foster the creation of professional learning communities that extend beyond a single workshop, offering ongoing support and collaboration – a key factor for sustained implementation (Trust et al., 2016).

Gaps and Future Directions

Despite promising models, the literature highlights several persistent gaps and challenges. First, there is a scarcity of longitudinal research tracking the long-term impact of such specialized technology workshops. While many studies report positive immediate outcomes in teacher knowledge, skills, and attitudes (based on pre- and post-workshop surveys), fewer follow teachers into their classrooms to assess the fidelity of implementation, the adaptations they make, and, ultimately, the effect on student learning outcomes and engagement over time (Shernoff et al., 2017).

Second, issues of scalability and equity require greater attention. Workshops hosted at or by large universities may be inaccessible to rural educators who are geographically isolated. Developing scalable models, potentially leveraging hybrid or online components for follow-up support, is essential for broader impact (Fishman et al., 2013). Equity also pertains to student access; PD must equip teachers with strategies to ensure that the integration of high-tech agriculture and robotics is inclusive and actively engages girls, students of color, and those from low-income backgrounds, groups historically underrepresented in both engineering and advanced agricultural careers.

Third, the assessment of teacher learning in these complex, skill-based workshops needs further development. Moving beyond self-reported surveys to include performance-based assessments, analysis of lesson plans developed, or classroom observation data would provide a more robust understanding of workshop efficacy (Guskey, 2014). Finally, there is a need for more research on the specific curricular and pedagogical strategies that are most effective for teaching agricultural robotics at the middle school level. This includes determining the optimal balance between teaching fundamental programming constructs and engaging in applied agricultural problem-solving, as well as identifying the most supportive instructional scaffolds for diverse learners.

Summary and Workshop Introduction

The modernization of K-12 education to reflect the technological realities of industries like agriculture is an imperative. This transformation is contingent upon the professional learning of teachers, who require support to navigate this convergence of disciplines. The scholarly literature converges on several key principles for success: PD must be content-focused, active, collaborative, and provide practical resources. It must address both technical skills and pedagogical content knowledge. The integration of robotics into subjects like agriculture offers a powerful, contextualized pathway for engaging students in computational thinking and engineering design. To realize this potential, investment in and research on sustainable partnership models – particularly those bridging universities and K-12 schools – is crucial. These partnerships can create agile, responsive, and relevant workshop experiences that empower teachers as confident, innovative practitioners capable of bringing the future of work into today's classroom rather than passive recipients of information. Future efforts must focus on longitudinal impact, scalable delivery mechanisms, and intentional equity. Such complex approach will ensure that all students, regardless of background or location, have the opportunity to become literate in the technologies shaping their world and their food systems. The following is the description of the workshop that aimed to address some of the PD challenges and concerns as discussed in the literature.

Workshop Description

Overview and Rationale

The rapid integration of advanced technologies into the agricultural sector is an integral part of I4.0 environment and presents both an opportunity and a challenge for K-12 education. To prepare students for future careers and foster STEM literacy, curricula must evolve to reflect the convergence of robotics, sensor technology, data science, and traditional agriscience. The workshop is designed to address the PD needs of Grade 6-8 STEM, agriculture, and computer science educators and boost their knowledge, skills, and ready-to-use resources to bring these cutting-edge concepts into their classrooms. The workshop is built directly upon the comprehensive "Smart Farming" curriculum unit developed by a multidisciplinary team, which provides a full 11-lesson pathway from historical context to hands-on robotics application.

The core rationale for this PD initiative is the critical gap between emerging agricultural technologies and current teacher preparedness. Many educators, particularly those without engineering or programming backgrounds, may feel apprehensive about teaching robotics or lack the contextual framework to make technology relevant within an agricultural or environmental science setting. This workshop directly addresses these barriers by demystifying block-based programming, grounding technological applications in authentic farming challenges, and providing a complete, standards-aligned curricular package. The goal is to introduce a new robotics kit and frame it as a tool for solving real-world problems in food production, thereby enhancing student engagement, computational thinking, and career awareness in high-demand fields.

Workshop Structure and Core Components

The proposed workshop is an intensive, hands-on PD experience structured to mirror the pedagogical approach of the student curriculum. It is designed to be conducted over one full day (approximately 6-7 hours) or two half-days, allowing for deep immersion. The workshop is divided into four sequential modules, each corresponding to a unit in the student curriculum, ensuring teachers experience the learning progression firsthand.

Module 1: Context and Connection – The Evolution of Farming and Technology (Approx. 1.5 hours)

This initial module focuses on building the "why" behind the technology. Rather than beginning with hardware, participants engage in the same historical exploration activity designed for students. Teachers are divided into groups to research and create collaborative timelines for either farming history or robotics history, culminating in a gallery walk and facilitated discussion. This activity serves multiple purposes: it models an inquiry-based, student-centered lesson; it visually demonstrates the parallel evolution of both fields; and it establishes a foundational understanding of how technological innovation has consistently transformed agriculture. The discussion then bridges to modern "Smart Farming," introducing key I4.0 concepts such as the Internet of Things (IoT), sensors, GPS, and automation. This module – among other things – ensures that teachers are familiar with the vocabulary and conceptual framework to effectively introduce it to their students.

Module 2: Hardware and Foundational Programming – Meet the *CuteBot* (Approx. 2 hours)

The workshop then transitions to hands-on skill development. Participants are introduced to the core hardware: the *CuteBot* smart car and its microcontroller "brain," the micro:bit. Trainers guide teachers through unboxing, basic assembly, and connection to the MakeCode block-based programming environment. The module is structured around progressive, scaffolded coding challenges. Teachers first write simple programs to control basic movement (forward, backward, turns), immediately building confidence and familiarity. The focus then shifts to sensor integration, starting with Infrared (IR) sensors for line tracking. Participants learn the logic of sensor feedback loops (e.g., "if left sensor detects white, turn right") and code their *CuteBot* to follow a black line. The second key sensor, the ultrasonic sensor for obstacle detection, is introduced next. Teachers program their robots to stop, signal with lights and sound, and react upon detecting an obstacle. This module is deliberately paced, emphasizing the iterative process of code, test, and debug that is central to both engineering and student learning.

Module 3: Applied Problem-Solving – Coding for Agricultural Challenges (Approx. 2 hours)

This module represents the heart of the workshop, where technical skills are applied to contextualized problems. Participants work in small teams to tackle a series of agricultural challenge scenarios drawn directly from the curriculum. Each challenge presents a real-world problem and asks teachers to design, code, and test a robotic solution using their *CuteBot*.

- Challenge 1: Navigating Crop Rows. Teams program their *CuteBot* to follow a winding path (simulating crop rows) using line-tracking logic, reinforcing precision navigation skills.
- Challenge 2: Perimeter Patrol. Teams code their robot to autonomously patrol a square or rectangular path (simulating a field perimeter), incorporating light and sound signals to indicate its patrol function.
- Challenge 3: Obstacle Detection and Avoidance. This more advanced challenge requires integrating ultrasonic sensor data to a) detect an obstacle and b) implement a decision-making routine (e.g., turn left or right, count the object, then resume its path).

Facilitators act as coaches, encouraging collaboration and troubleshooting. This module explicitly models the collaborative group work that teachers will be expected to facilitate with their students, while also addressing the pilot workshop observation that teachers themselves tended to avoid teamwork. Time is dedicated to discussing how to manage group dynamics, differentiate instruction, and assess student progress on such open-ended projects.

Module 4: Integration, Careers, and Implementation Planning (Approx. 1.5 hours)

The final module looks beyond the robotics kit to broader integration and future implications. It begins with a dynamic career exploration activity. Teachers brainstorm traditional agricultural careers and then are presented with modern counterparts (e.g., Drone Operator, Precision Agriculture Specialist, Robotics Technician, Data Analyst). This activity highlights the expanding spectrum of tech-driven agriculture-related careers, a key curriculum objective.

The practical implementation of the workshop is the following. The facilitators present the full suite of accompanying curriculum materials: detailed lesson plans, student handouts, pre/post assessments, vocabulary quizzes, PowerPoint slides, and supplementary resources. Then the facilitators and teacher participants go though the modules with a coffee break in the middle. The workshop concludes with a Q&A session and a formal commitment to ongoing support, such as a follow-up virtual check-in or access to a shared online resource portal for participating educators. Future workshop sessions may offer a follow up meeting (in-person and/or virtual) that would allow teachers to map the 11-lesson unit into their existing academic calendar, identify potential cross-curricular connections (e.g., with science, social studies, etc.), and discuss strategies for securing funding or administrative support.

Workshop Results

The results from the "Smart Farming: The Future of Agriculture" teacher workshop reveal significant and positive shifts in participants' self-reported comfort levels across all targeted knowledge and instructional domains. The participants were recruited through a variety of channels, such as the dedicated K-12 teacher listserv, posts in social networks, and the preceding public events of the AgBridge program. Most teacher participants represented different school districts from across the state with only two being from the same school district. The authors used a pre-/post-test assessment model with identical Likert-scale questions to measure changes in participant confidence. The assessment also included the qualitative component to provide an option for extended written feedback. The data were collected through an online form. The participants could access the form by scanning a QR code in the presentation slide at the specified times during the workshop event.

Pre-Test Results: Baseline Comfort Levels

The pre-test, completed by eight (8) workshop participants, established a baseline of teacher self-efficacy prior to the PD. The questions measured comfort on a Likert scale across five key areas:

1. Teaching the evolution/history of farming and traditional methods: Responses showed a relatively high initial comfort level, with the majority of teachers reporting they were "Comfortable" or "Very comfortable." This suggests participants entered with a stronger foundational confidence in core agricultural content than in technology integration.
2. Teaching robotics and coding: This area showed the lowest baseline confidence. Responses were spread across "Neutral," "Comfortable," and "Very comfortable," but a notable portion indicated neutrality, revealing apprehension or lack of experience with these technical subjects.
3. Leading students through a robotic coding challenge: Similarly, confidence here was modest, with responses concentrated in the "Neutral" to "Comfortable" range. This indicates that even teachers who felt somewhat okay with the concepts of robotics were less sure about pedagogically guiding students through hands-on, problem-based coding tasks.
4. Teaching about autonomous robots in agriculture: Comfort levels were mixed, leaning toward neutral. This reflects the specialized, interdisciplinary nature of the topic, which combines agriculture, robotics, and real-world application – a likely new area for most attendees.
5. Discussing/counseling students toward careers in agriculture: Pre-workshop comfort was moderate, with most responses in the "Neutral" and "Comfortable" categories. This suggests that while teachers had some awareness of agricultural careers, they may have lacked knowledge of the modern, technology-driven career pathways emphasized in the workshop.

In summary, the pre-test data described educators who were generally confident in teaching historical agriculture but expressed significant uncertainty – ranging from neutrality to moderate comfort – when it came to the integrated technological and pedagogical skills required for delivering the smart farming curriculum.

Post-Test Results: Measurable Gains in Confidence

The post-test, completed by five (5) participants, demonstrated clear and substantial improvement in self-reported comfort across all five measured areas. The Likert-scale responses showed a marked positive shift:

1. Teaching the evolution/history of farming: Comfort solidified at the highest end of the scale, with all respondents now reporting they are "Comfortable" or "Very comfortable." The workshop successfully reinforced or enhanced their confidence in this foundational area.
2. Teaching robotics and coding: This area showed one of the most dramatic improvements. The spread of responses collapsed, with all post-test respondents indicating they were now "Comfortable" or "Very comfortable." The neutral and uncertain responses from the pre-test were eliminated.
3. Leading a robotic coding challenge: Mirroring the gains in robotics knowledge, confidence in pedagogical leadership surged. All post-workshop responses were in the "Comfortable" or "Very comfortable" range, indicating that the hands-on, participatory model of the workshop effectively prepared teachers to facilitate similar challenges for their students.
4. Teaching about autonomous robots in agriculture: Post-test results showed a strong consolidation of confidence, with respondents moving squarely into the "Comfortable" and "Very comfortable" categories. The workshop successfully connected the abstract concept of autonomy to tangible agricultural applications.
5. Discussing agricultural careers: Confidence in career counseling showed strong improvement, with respondents moving from the neutral/comfortable range to being uniformly "Comfortable" or "Very comfortable." This indicates the career exploration components of the workshop effectively expanded teachers' perceptions of the agricultural sector.

Analysis of Outcomes and Qualitative Feedback

The quantitative data from the Likert-scale questions confirms the workshop's primary outcome: a significant increase in teacher self-efficacy regarding the integration of robotics, coding, and smart farming concepts into their middle school curricula. The most pronounced gains were in the areas of greatest initial need – robotics, coding, and their applied use in agriculture.

The qualitative feedback from the post-test open-ended question further enriches this picture. Comments such as *"Excellent presentation- I'm anxious to try some of this in class"* and *"I would be interested in providing feedback about how the lessons go in my classroom"* point to high levels of engagement, perceived value, and intent to implement the curriculum. These statements transition the measured outcome from increased confidence to anticipated behavioral change in classroom practice. The request for data and ongoing feedback (*"Might I be able to get data from teaching teachers?"* and *"I would like to give feedback..."*) also suggests the participants are viewing the experience as the start of an ongoing learning process and potential community of practice, rather than a one-off event.

In conclusion, the workshop results demonstrate clear success in achieving its PD goals. The pre-/post-test model with Likert-scale questions effectively captured a positive shift from apprehension and neutrality to confidence and readiness. The outcomes indicate that the workshop structure – which combined content knowledge, hands-on skill development, pedagogical modeling, and resource provision – was effective in empowering teacher participants to bring complex, interdisciplinary STEM concepts on smart farming and robotics into their middle school classrooms.

Discussion

The design, execution, and results of the "Smart Farming" robotics workshop for middle school teachers align closely with established principles of effective PD and directly address specific gaps identified in the literature on STEM teacher education. The significant gains in teacher self-efficacy, particularly in technical and pedagogical domains related to robotics, validate the efficacy of the workshop's hands-on, contextualized, and resource-rich model. This success can be attributed to several key factors that resonate with scholarly recommendations.

First, the workshop structure directly embodied the core features of high-quality PD: content focus, active learning, and coherence (Desimone, 2009; Garet et al., 2016). The entire experience was centered on the specific, interdisciplinary content of agricultural robotics. Rather than offering abstract theory, it immersed teachers in "learning by doing," requiring them to program, troubleshoot, and apply the *CuteBot* to solve authentic problems – an approach shown to build both skill and pedagogical confidence (Eguchi, 2014; Menekse, 2015). The coherence was ensured by providing a complete, standards-aligned curriculum package, directly addressing the common teacher complaint that PD lacks practical, classroom-ready materials (Darling-Hammond et al., 2017). The increased post-workshop confidence in leading coding challenges suggests that experiencing the curriculum as a learner provided teachers with the necessary pedagogical content knowledge to implement it effectively.

Second, the workshop leveraged a university-K-12 partnership model, a strategy highlighted in the literature as a potent catalyst for innovative PD (Laursen et al., 2012). The collaboration between STEM graduate students and a K-12 professional allowed for a synergistic exchange: graduate students contributed cutting-edge technical expertise and enthusiasm, while the K-12 partner ensured pedagogical relevance and classroom feasibility. This model enhanced the "timeliness" of the content, bridging the rapid pace of I4.0 with K-12 practice, and provided valuable outreach and communication experience for the graduate students (Andrews et al., 2020). The voluntary, project-based nature of the initiative, as part of a broader workforce development program, likely fostered the innovation and commitment observed in the workshop's design and execution.

The most compelling evidence of the workshop's impact is the quantitative and qualitative shift in teacher self-efficacy. The pre-test data confirmed a known barrier: while comfortable with traditional agriculture, teachers exhibited significant apprehension about robotics, coding, and their integration – a common challenge documented in research (Yadav et al., 2017). The post-test results demonstrated that a single, intensive workshop can substantially mitigate this barrier among the participants. The elimination of "Neutral" responses in key technical areas and the consolidation of confidence into "Comfortable" and "Very comfortable" categories indicate a successful intervention. This aligns with findings that targeted, hands-on workshops can effectively boost teacher confidence in technology integration (Shernoff et al., 2017).

The qualitative feedback revealed a crucial outcome beyond confidence: the intent to implement and a desire for sustained engagement. Comments expressing eagerness to try the lessons and provide feedback suggest the workshop successfully transitioned teachers from passive recipients to active, invested practitioners. This moves toward creating a professional learning community, which is critical for long-term implementation success (Trust et al., 2016). The facilitators' request for ongoing data and feedback also presents a valuable opportunity for the kind of longitudinal partnership and research called for in the literature.

The workshop results have certain limitations as follows. The small sample size (n=8 pre, n=5 post) and reliance on self-reported data are the areas for future improvement, although common in PD evaluation. The assessment captures perceived confidence (Level 2 of Guskey's framework) but not actual implementation fidelity or student learning outcomes (Levels 3 and 4) (Guskey, 2014). The workshop also faced practical challenges, such as lower post-test participation and the observation that teachers initially avoided collaboration – a behavior that the workshop design had to consciously model and encourage. These observations highlight the importance of designing PD that explicitly teaches and practices collaborative skills for the teachers to pass on the same practices to their students.

Finally, the workshop illuminates the urgent need to modernize agricultural education. By contextualizing robotics within challenges like crop row navigation and perimeter patrol, the curriculum effectively demonstrated how I4.0 technologies are reshaping agri-food systems (Wolfert et al., 2017). The significant improvement in teachers' comfort discussing agricultural careers indicates an expanded awareness of the field, helping to dismantle outdated perceptions and guide students toward high-tech, in-demand pathways (Lawson et al., 2020).

Conclusion

This workshop initiative demonstrates a viable and effective *model* for addressing the critical PD gap at the intersection of K-12 STEM education and modern agriculture. By integrating a hands-on robotics curriculum within the authentic context of smart farming challenges, and by leveraging the dynamic partnership of university graduate students and K-12 educators, the project successfully equipped middle school teacher participants with the knowledge, skills, resources, and the confidence to bring advanced technological concepts into their classrooms.

The results affirm that carefully designed, applied workshops can rapidly build teacher self-efficacy in complex, interdisciplinary domains. The provided curriculum aimed to reduce the barrier to implementation and ensure that teacher learning translates directly into classroom practice. The model also highlights the mutual benefits of embedded university-K-12 partnerships, which can serve as agile pipelines for translating emerging research and industry trends into timely, relevant learning experiences for students.

The outcomes of the workshop allow the authors to make the following considerations. Firstly, further research will incorporate longitudinal evaluation strategies that track classroom implementation and student impact. Secondly, the described workshop model can be adjusted for scalability and the consecutive “statewide” workshop sessions, with particular attention to accessibility for rural educators. Thirdly, intentional efforts to build sustainable communities of practice around such curricula will be essential for supporting teachers beyond the initial workshop. Finally, the authors advocate for continued investment in these cross-institutional collaborations. The empowerment of teachers as facilitators of agricultural robotics is an enhancement to STEM education that contributes to making future workforce capable of driving innovation, sustainability, and security in one of the nation’s most vital industries – agricultural industry. The project provides a working example of such empowerment, one workshop and one classroom at a time.

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