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Creating Agricultural Technology Lessons for High School Students to Stimulate Interest in Long-Term Career Possibilities and Collegiate ABE and ASM Matriculation

Dr. Robert Merton Stwalley III, Purdue University at West Lafayette (COE)

Dr. Robert M. Stwalley III, P.E. joined the Agricultural & Biological Engineering department as a faculty member in the fall of 2013. He earned his Bachelor of Science in Agriculture and Biological Engineering (ABE) and his M.S.E. and Ph.D. from ME.

Creating Agricultural Technology Lessons for High School Students to Stimulate Interest in Long-Term Career Possibilities and Collegiate ABE and ASM Matriculation: A Work-in-Progress

Abstract

Agriculture represents a large segment of the economy in the United States, particularly within the inter-mountain region in the center of the country. The technology associated with agricultural pursuits is growing ever more complex. The labor pool associated with farm and ranch operations and agricultural support service providers will need to deal with increasingly complex equipment requiring specialized training. Researchers from Purdue Agricultural & Biological Engineering have received funding from USDA-NIFA to develop learning modules for high school instruction that could help stimulate interest in the ongoing activities of the agricultural industry. These exercises will incorporate off-road vehicle balance and design elements, robotics and programming, and unmanned aircraft systems and instrumentation. These lessons will be piloted at a career center run jointly by three local public school corporations, near the university. Details of the lesson planning strategy, physical lab activities, and overall learning objectives will be presented.

Keywords

Agricultural Instruction, Hands-on Learning, High School, Lesson Plans, STEM

Introduction

Throughout the world, the popular press is currently filled with articles describing the shortage of workers in all segments of industry following the pandemic of 2020-2021. This is particularly true in US agriculture [1]. Multiple trends are aligning to exacerbate this problem [2]. Farm sizes are growing, while the number of farms is decreasing [3]. The number of ‘family farms’, where young people are raised in conjunction with livestock and agricultural equipment, has fallen dramatically, while corporate farms have risen [3]. This has adversely affected the number of young people that have grown up with agricultural experiences, making recruiting people to work in agricultural operations more challenging and difficult [2]. This is true across the globe, regardless of the overall state of the local economy [4]. Individuals with no agricultural experience are far less likely to choose an agricultural career, as they may believe that it is undignified or somehow of lesser importance to society [5].

The lack of a connection to agricultural work hinders the recruitment of potential employees. Still, another factor limits the suitability of those inclined: the complexity of modern agricultural equipment [6]. Hiring someone with little or no experience in agriculture and having them functionally trained to operate certain equipment within a few hours of instruction is no longer possible [7]. Tractors, combines, silage choppers, and sprayers are now all highly computerized machines, requiring extensive training and an initial understanding of physical operations, common machine adjustments, and electronic systems. As shown in Figure 1, John Deere® currently produces multiple machine simulators to train potential operators to adjust and optimize operations using their sophisticated onboard electronic systems. Anecdotally, Purdue Agricultural Systems Management (ASM) undergraduate students, who complete the lessons for extra credit in the current sophomore-level crop production equipment course, report committing between 20 to 40 hours to the full sequence of training modules.

Faculty in Agricultural & Biological Engineering at Purdue are keenly aware of this trend as they have watched agricultural demographics change and the level of incoming practical agricultural experience in their students decline. They are motivated to address the problem. A USDA-NIFA-sponsored program to introduce high school students to some of the more modern and technically challenging aspects of agricultural equipment is under development in hopes of demonstrating the high-tech nature of modern agriculture. Young people that have already experienced the benefits of electronics in their lives would seem to be a perfect fit for the modern applications of technology. This program is designed to provide them with an introduction to the use of modern technology in agriculture and help them to understand that they already have many of the tools needed to participate in this exciting and vital industry. These new modules will incorporate significant hands-on learning experiences, as they have been previously shown to be specifically appealing to the types of students who may gravitate toward these fields [8] [9]. These short individual learning modules should provide enough introduction and comprehension of the three subjects to qualify as proceeding through the knowledge, comprehension, application, and analysis levels on the original Bloom taxonomy [10] or making progress toward factual, conceptual, and procedural knowledge on the updated taxonomy [11]. They will be broadly project-based and able to be evaluated similarly to other project / team experience exercises using skills evaluations and teamwork rubrics [12] [13].

Figure 1 – Purdue University Agricultural Systems Management (ASM) undergraduate students working on a John Deere® combine simulator, learning to use the onboard electronic harvest optimization software.

Under the terms of this grant, three lesson plans for high school students, teaching modern agricultural equipment skills, will be developed and pilot-taught once for implementation and post-implementation improvement by the developers. An IRB-approved pre- and post- knowledge test and open-ended response survey will initially be used to evaluate the newly created materials. The overall program is intended to involve three technology-based hands-on lessons, each lasting 5 weeks. These lessons consist of instruction in aerial drone operations, off-road vehicle balance, and the construction and operation of small agricultural robots. The modules are independent and can be implemented in any order. The physical elements and instructor's curricular needs for these three modules, comprising a single high school semester 'credit hour', will be developed. Initial plans call for utilizing the Greater Lafayette Career Academy (GLCA), a combined high school of the three public school systems in Tippecanoe County, Indiana, as the test facility. This will allow the instructor to have close contact with the faculty members developing the modules. The developed lesson plans contain clearly-identified learning objectives, lecture notes and slides, hands-on exercises, and assessments, and they will meet overall standards for high school curricula. The three specific modules selected, concentrating on aerial drone operation, off-road vehicle balance, and agricultural robotics, were chosen as engaging technology-based agricultural elements that were age and experience appropriate for teenagers. These topics were also evaluated for their perceived 'sizzle' to appeal to high school students. Assessments will be performed through a pre- and post- survey of the student participants in the courses. The remainder of this paper will describe the ongoing efforts to develop the curricular materials for these five-week modules, describe the difficulties encountered to date, and the plan for future efforts and dissemination.

Aerial Drone Operation

Unmanned aircraft systems (UAS), known popularly as drones, are have been increasingly applied to agricultural operations, due to the relatively easier learning curve associated with their operation, user-friendly regulations, and affordability of the technology. Drones, like those shown in Figure 2, serve as a stable aerial platform, and once fitted with a variety of sensors, such as off-the-self cameras, multispectral/hyperspectral sensors, or thermal sensors, they can remotely collect invaluable information about the current crop and ground conditions. Drones are an important component of modern digital agriculture, as they enable on-demand data collection. Due to the vantage view by drones, improved analysis methods are currently being researched to manage plants and animals in a more efficient manner, and the demand for individuals with experience in the field has skyrocketed.

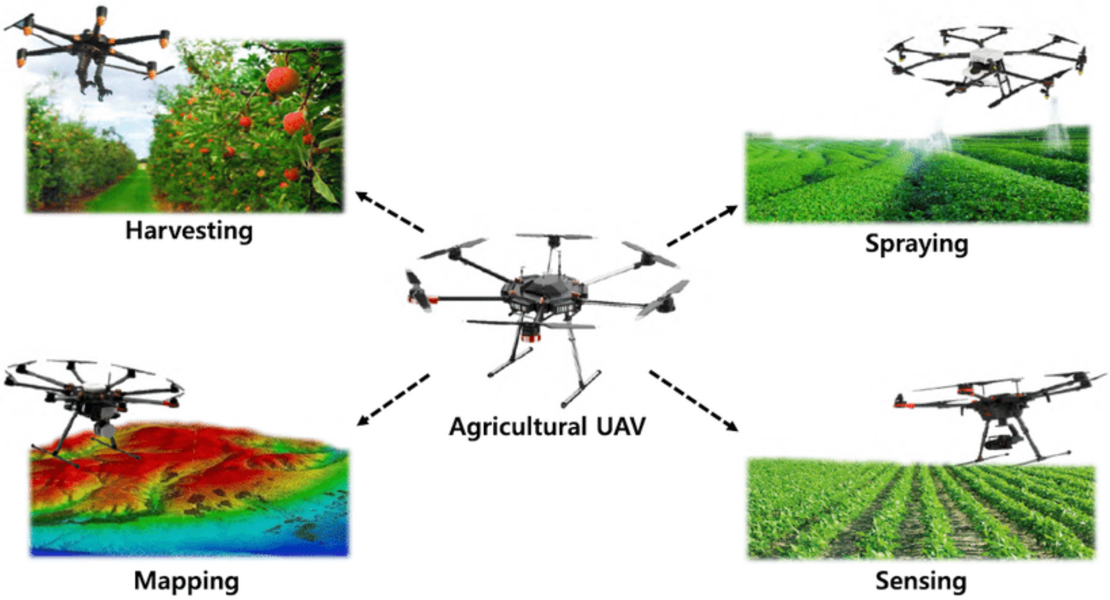


Figure 2 – Unmanned aircraft system (UAS) activities in the agricultural industry.

Introducing a course module on agricultural drones could potentially encourage rural high school students to enroll in courses that would prepare them for pursuing an agricultural or aviation-related career at an institution of higher education. Several positive indicators, such as the global agricultural drone market projected to become an approximately USD 17.0 billion industry by 2027 [14] and 100,000 new jobs in the field by 2025, due to the integration of UASs in nearly every sector of the economy, point to an increasing need for exciting rural youth about science and technology related careers [15]. Although it is a relatively easy task to attract students into flying UASs, providing a career connection requires the development of a deep enough interest to engage them in an advanced curriculum that makes them suitable to be hired by the industry.

The preliminary learning objectives for the introductory high school UAS lesson are to be able to:

1) Define a drone and types of drones;
2) Identify the major components of a drone and its function;
3) List the advantages of using drones in plants and animal agriculture;
4) List various sensors that can be used with a drone;
5) Define drone remote sensing;
6) Learn visual coding to control various drone operations;
7) Learn to integrate sensors with drones; and
8) Learn to collect data using drones.

The course module will consist of PowerPoint lessons and hands-on learning exercises to allow ag teachers to teach the core concepts. The hands-on coding portion will be challenge-based, with the students working in teams to complete given exercises. The students will learn to collect data by selecting appropriate sensors, determining flight lines, and planning the mission, as per the task of their interest. Teams that complete all of the assignments properly will be encouraged to compete in an annual statewide competition, similar to the current NASA drone competition or other organized youth drone contests.

Off-Road Vehicle Balance

This section of the project explores the off-road vehicle balance problem within a team-based, challenge environment. While the physics of the problem is identical to balance for on-road vehicle use, it is of great practical significance in off-road vehicle operations, as the centers of gravity in these vehicles are higher and more variable. One-third of all agricultural and construction equipment accidents result from vehicle overturn, upset, or loss of stability [16]. The overall learning objectives for this module are to be able to:

1) Understand the concept of the torque, levers, and summing moments;
2) Calculate a center of mass;
3) Understand the concept of force vectors and the summing of forces;
4) Calculate the normal reaction forces on a stationary, static vehicle;
5) Calculate the forces on a vehicle under load in a pseudo-dynamic state with a fixed hitch position;
6) Calculate the forces on a vehicle under load in a pseudo-dynamic state with a varying hitch length and height;
7) Calculate the forces on a vehicle under load in a pseudo-dynamic state with various ballast amounts and positions;
8) Understand the concept of gear ratios and transmission;
9) Calculate distance, force, work, energy consumed, and power delivered; and
10) Understand the trade-offs associated with design.

These objectives are intended to build upon a general high school level of understanding of the fundamental principles of mathematics and physics and be taught progressively.

It is envisioned that a traditional hinged bar and weight experimental set-up from beginning physics laboratories, as illustrated in Figure 3, can be utilized for instruction in the first objective. Objective #2 is analytical and will involve problem solving. A vector table with pulleys and weights, also from high school physics labs, and shown in Figure 4, is planned for use in teaching objective #3. Objective #4 can be taught using individual truck tire scales, an example of which is provided in Figure 5, or alternatively, using contact paper and tire pressure gauges. The remaining learning objectives for this vehicle balance module will involve using a small-scale pulling tractor that the students can either have provided or be allowed to assemble. The pulling tractor has been based upon a University of Kentucky Biosystems & Agricultural Engineering (BAE) design, shown in Figure 6, while the restraining tower and weight system design was from Purdue University Agricultural & Biological Engineering (ABE). Variations of the tractor's reaction under varying hitching conditions will be explored for objective #5. Allowing the tractor to move under load will demonstrate the changes from loads applied in motion, objective #6. Experimentation with front-end ballast will form the core of objective #7. The overall reaction of the tractor to pulling loads under different transmission settings will be explored with objective #8. Analytical lessons will convert the collected data from the experiments into accepted metrics that are commonly used to compare different off-road machines. The main module will conclude with a technical trade-off lesson, based on a pulling contest using the model tractor. Additional topics that could potentially be explored with this set-up include front-to-back roll-over, side-rolls, front-end loaders, four-wheel drive, and power hop.

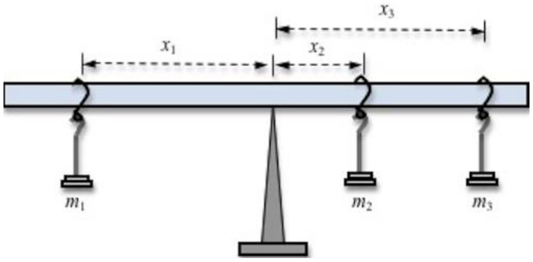


Figure 3 – A balance bar physics experimental set-up.

Figure 4 – A vector weight table physics experimental set-up.

Figure 5 – Individual tire scales for vehicles to determine wheel weights.

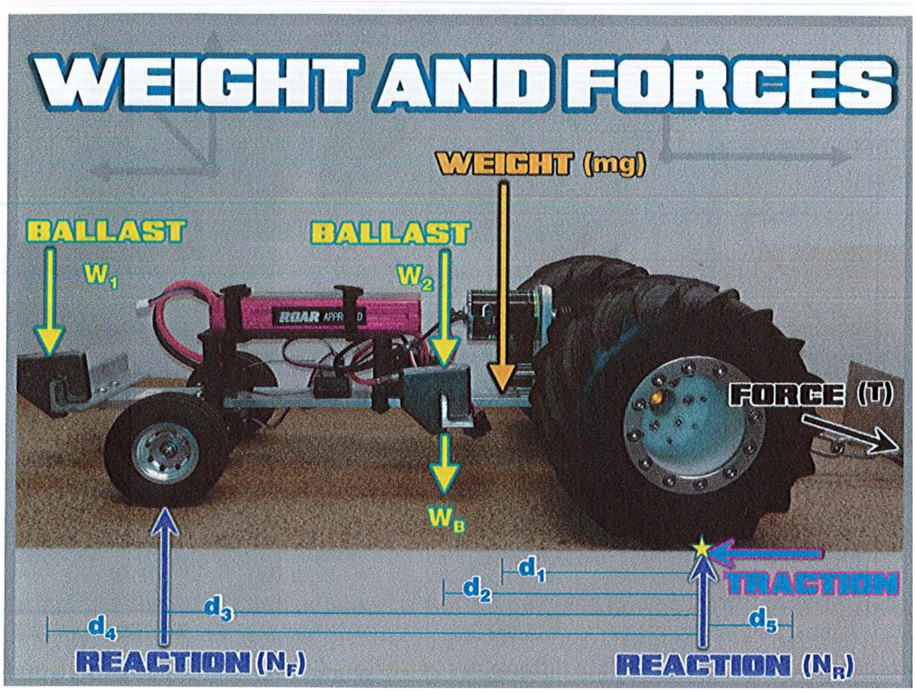


Figure 6 – A free body diagram (FBD) for the tractor balance problem overlaid on a typical miniature pulling tractor developed by the University of Kentucky Biosystems and Agricultural Engineering Department.

Before starting this module, students will be expected to have a beginning knowledge of algebra and vectors. These lessons will incorporate the concepts of the summing of forces and moments from basic mechanics. Students will calculate axle loads on vehicles in a variety of configurations, and then they will experimentally determine those loads to check their predictions. Modifications resulting from hitching and ballast changes will be explored. The students will experiment with the ramifications of transmission gear ratios, vehicle weight, center of gravity, and stability. The efficient and safe use of complex vehicles in the agricultural and construction industries requires knowledgeable individuals that understand the basics of vehicle balance. The hope is that students can see the intriguing complexities associated with the trade-offs in the design of off-road vehicles and wish to learn more at a collegiate level.

Agricultural Robots

The technical sophistication of agricultural equipment continues to grow, and robotic elements are playing a big role in the increase. Finding enough people with the skill sets and training to operate modern equipment is challenging. Crop production equipment, such as agricultural tractors, row crop planters, grain drills, and self-propelled sprayers, have sensors to detect operating conditions, computers to run prescriptive programs defining how these machines respond to inputs, and actuators to make the specific changes and modifications [17]. These large-scale agricultural machines fit the definition of mobile robots, and their operation at an optimal level requires a detailed knowledge and understanding of multiple topics. Even precision livestock production requires an in-depth understanding of electronic sensors and data collection [18].

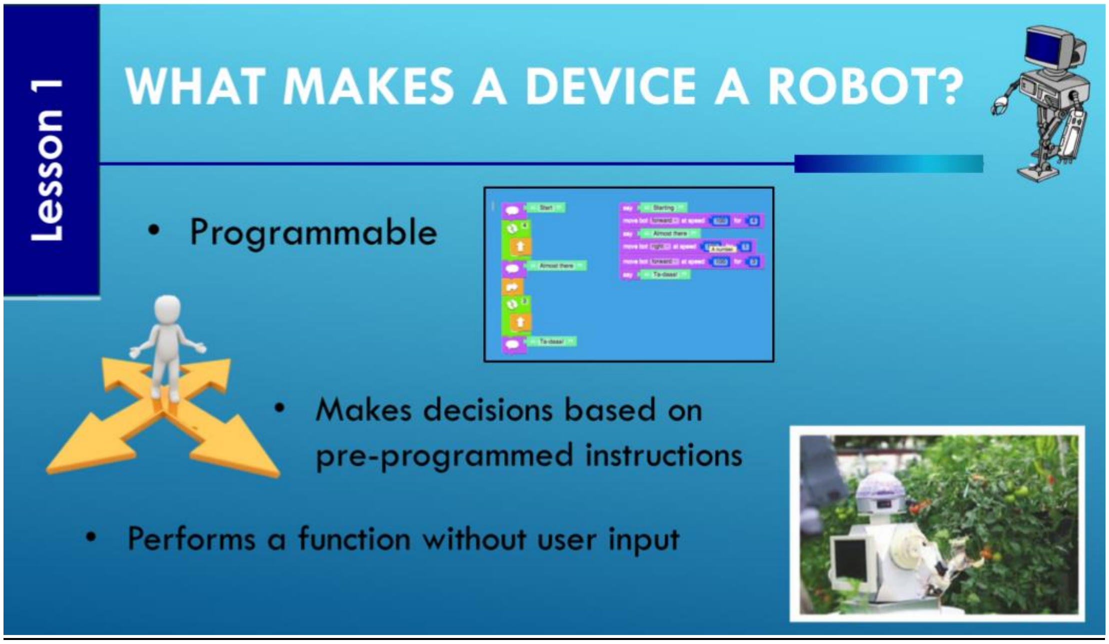
To enhance the technical skills and motivation in the area of agricultural robotics for the project’s target audience of students in rural high school agricultural science programs, the robotics portion of this curriculum will provide the student with a basic understanding of design principles, electrical components, electronic sensors, data collection, and basic coding. Team-based, hands-on design challenges will be implemented to create an educational environment that motivates and challenges the high school agricultural science students to seek further collegiate knowledge that will enable them to solve real world food security issues.

The initial learning objectives for the robotics curriculum are to be able to:

1) Define a robot;
2) Determine if a machine is a robot;
3) List the major components of a robot;
4) State the function of the major robotic components;
5) List the advantage of using robots in agriculture;
6) List the uses of robots in rural and urban-based agriculture;

7) Calculate the theoretical speed of a robot;
8) Create the code needed for a robot to perform a basic function;
9) Successfully integrate sensors into a robot; and
10) Work on a team to develop a design and construct a contest robot.

It is envisioned that the agricultural robot five-week curriculum module will consist of two major sections that will span the entire five-week period. The first section will be a traditional classroom-based, utilizing PowerPoint® lessons, like the one in Figure 7, and focused hands-on learning activities to teach the core concepts. The classroom piece will consist of ten 50-minute lessons, totaling two weeks of instruction. The hands-on design portion will be challenge-based, with the students working in teams of three to four to design a table-top size robot to solve a simulated agricultural problem, similar to that shown in Figure 8. Teams will compete annually in a statewide competition, similar to the current ASABE competition or other youth robotics contests. The design challenge for the contest will change annually to allow students to design a new robot to complete the new relevant agricultural task.



Lesson 1

WHAT MAKES A DEVICE A ROBOT?

- Programmable
- Makes decisions based on pre-programmed instructions
- Performs a function without user input

Figure 7 – An example of a typical PowerPoint® slide from agricultural robotics lesson.

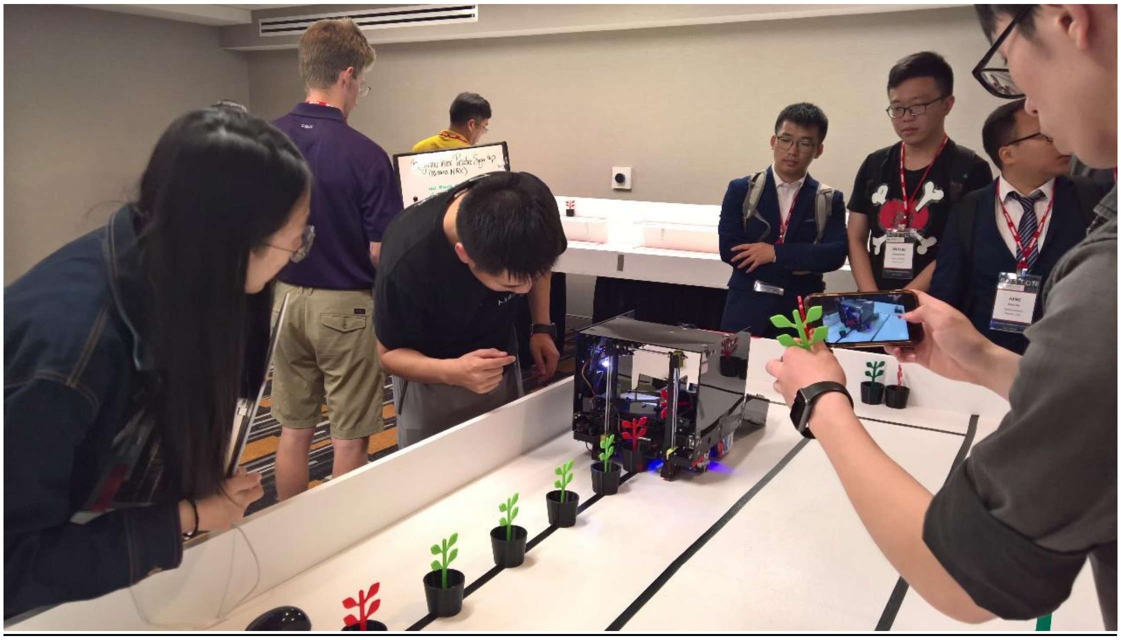


Figure 8 – A student-designed autonomous robot sorting plants, based on color and leaf configurations, in a simulated greenhouse operation.

Conclusions and Future Efforts

The university faculty's motivation for developing these learning modules was to provide high school agriculture teachers with ready-to-execute, grade-level appropriate instructional materials that could demonstrate to students that contemporary agricultural processes and machinery make use of high technology and that a satisfying career can be developed involving these modern industrial marvels. The researchers hope to provide a more detailed look into the specific lessons and student assignments in future publications, along with the course assessment surveys and the adjustments recommended following the initial implementation of the courses. The aerial drone module will introduce sensors, data collection, and a modern, working UAS. The tractor balance module will emphasize vehicle dynamics and safety through experimentation and computational analysis. Finally, the agricultural robot module was designed to highlight computer programming skills and the use of small machinery to perform complex repetitive tasks. The development process for these modules was designed to move through an initial year's implementation at GLCA, the local public school career center. Although module development has proceeded slower than expected, difficulties in using the GLCA center to alpha-test the products have also arisen, primarily due to their inability to hire an agricultural teacher for the center. Currently, certified agriculture teachers seem to be as hard to find as on-farm labor. An alternative execution plan at another, more distant school has been prepared, if it proves unfeasible to use the GLCA as the initial testbed for these modules. Under either circumstance, the lesson plans will receive a preliminary utilization within the target market of students and be improved through one round of revision before wider publication, dissemination, and general release.

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