Mapping Learning Outcomes Across Biological and Agricultural Engineering Concentrations Within the Curriculum

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Biological and Agricultural engineers possess knowledge, skills and abilities which allow them to work in many technical sectors. Oftentimes, due to their breadth of knowledge and lack of exposure, they must distinguish themselves from other engineering disciplines. Biological and Agricultural engineering (BAE) undergraduate curricula provide students with an opportunity to specialize their learning in specific concentrations such as water and soil conservation, air quality, agricultural systems/power & machinery, renewable energy, and post-harvest processing/food engineering/bioprocess engineering. In an effort to identify distinguishing characteristics of a BAE, learning outcomes were mapped to specific concentrations and specific knowledge areas for the BAE curriculum at Texas A&M University. Learning outcomes have been viewed as the standard for measuring the knowledge, skills and attitudes a student has obtained. Mapping of these learning outcomes could function as indicators of students' abilities to perform in careers focused on their concentration and distinguish them from graduates of other disciplines. In an effort to develop a more holistic picture of the discipline for students and employers, faculty from the department at this university identified learning outcomes (LOs) (labeled 'a' through 'at') which shape the development of a BAE student in any concentration area. Learning outcomes of four concentrations within BAE program were analyzed, across 19 specific knowledge areas (KAs). Results indicated that specific KAs overlap across concentrations, and the most common learning outcome was post-harvest/food engineering/bioprocess engineering. It was determined that the initial knowledge areas could be reduced by combining common themes to still fit the correlated learning outcomes. The primary goal of this work was to identify the learning outcomes mastery and specific knowledge areas that BAE students should gain through core curriculum courses. This research problem was addressed through analysis and frequency clustering of an existing report, by exploring the following investigative question: 1) what are the specific knowledge areas that define a BAE graduate despite concentration/area of emphasis and 2) how do the top learning outcomes, knowledge areas and concentrations describe the BAE program and expectations of the graduates. The results from this mapping were the first steps in identifying gaps in knowledge and technical expertise areas students possess before entering their careers. In the future, these results will be combined with mapping of other outcomes and faculty input to inform the development of learning modules specific for training of BAE going into industry and extension careers.

Introduction

The field of Biological and Agricultural Engineering is an aggregation of the farmer, the merchant, and the agricultural engineer [1]. However, in recent years it has struggled to be differentiated from environmental engineering and biomedical engineering. Students, graduates and faculty of this field often revisit the question: what distinguishes a Biological and Agricultural Engineer from a Civil, Environmental, Chemical or even Mechanical Engineer? There are multiple factors which contribute to this question and the diversity of BAE programs including the varying names across universities, varying areas of emphasis or concentrations and varying learning outcomes. Across universities in the United States, 14 unique names for BAE degree programs in this field have been identified; most common are Biological Engineering

(24%) with 82% of the programs including the term bio- and 38% of the programs including the word agriculture [2]. Despite the variations in the name, the program has been defined as one which applies engineering principles and concepts of biology to both agricultural and biological systems and tools [3]. Early attempts were made to define important parameters of the major for institutions attempting to develop BAE programs [4]. Concentrations, or emphasis areas, within the field generally include soil and water engineering, post-harvest processing/food engineering/bioprocess engineering, renewable energy, power and machinery engineering, structures and environment varying emphasis areas lead to varying learning outcomes across universities. These concentrations represent the area of emphasis students identify as their direction of study within the program, and generally it will guide the student through the selection of their upper level and elective courses. The training of the BAE includes principles from and common to electrical, mechanical, chemical and civil engineering [4]. Often first and second year engineering students are unable to identify characteristics which are distinguishable only to BAE students, until they reach their specific area of interest or concentration.

As we inch towards 9 billion people in 2050, the Biological and Agricultural Engineer will play an integral part in managing the soil, water, food and energy necessary to sustain us all. Generally large companies develop relationships with BAE programs at specific universities, based on alumni and faculty interactions. Potential employers have a hard time recruiting BAE graduates into positions for their engineers due to variations in program names and a lack of a universal understanding of graduates' knowledge, skills and abilities [2], [5]. To meet these needs of current and potential employers, learning outcomes within the discipline should reflect employer expectations of the graduates to perform a job. Identifying the top learning outcomes for the field will assist in defining the major for potential employers as well as current and potential students across universities.

There are many models available to guide engineering disciplines as they reshape their curricula. Morsi et al. [6] used concept mapping for curriculum development, specifically Electrical and Computer Engineering curricula. Models to evaluate the development and design of interdisciplinary curricula through the integration of learning modules gave students a real-world application for learning outcomes [7]. There have been great strides in evaluating the curriculum of the Agricultural and Bio-based engineering programs, referred to in this work as BA engineering, as noted in recent works [2], [8], [9], [10], [11]. Lohani et al. [12] explored the use of a spiral down concept to redesign their Biological Systems Engineering program. Johnson et al. [8] evaluated the biological engineering program at one university as it transformed its curriculum and saw major enrollment growth. One common thread through all of these reports is that the program is highly impactful but hard to define as small variations across campus programs make it difficult to categorize.

In developing a universal picture of the discipline, we can evaluate the learning outcomes for each student, unrelated to their potential concentration. Learning outcomes are defined as being clear, observable and measurable [13], [14]. Learning outcomes should focus on knowledge, skills, and abilities that students should obtain or possess by the end of the course [15]. Michelson et al. [13] notes the importance of learning objectives and that they can be analyzed through a complex process which lead to various outcomes.

This paper describes learning outcomes and specific knowledge areas that a Biological and Agricultural program identified for their graduates. The study begins by evaluating a list of learning outcomes compiled by select faculty at a large south-central university and the specific knowledge areas and concentrations for each outcome. It introduces a method to rank the knowledge areas in an effort to identify which learning outcomes correlate to the highest ranked knowledge areas. Results are presented in tables with separate discussions linking to the established literature.

Methods

The following documents the step-wise process that was developed to identify specific knowledge areas that were critical to learning outcomes for BAE. An existing report from the departments curricula committee was analyzed by arranging the observations into emphasis areas, linking specific knowledge areas to learning outcomes, then agglomerating and ranking according to frequency of concept.

Learning outcomes linked to specific knowledge areas within BAE Concentrations
The 46 learning outcomes were ordered under four concentrations within the program. Faculty within the department identified specific knowledge areas (KAs) for each of the learning outcomes. KAs are general knowledge concepts that are taught throughout the major curriculum and required in order to address the learning outcomes. For example, the specific knowledge area "*Psychrometrics*" was assigned to the learning outcome *(a) Given any two parameters (e.g. temperature, humidity, enthalpy, etc.) determine all other parameters in moist air*. At times multiple KAs were required to accomplish a learning outcome (LO). The 46 LOs labeled in this work 'a' through 'at' and listed in Table 1, and 19 KAs were used to show how the mapping connections would demonstrate that student's proficiency in a general knowledge area.

Table 1. Specific Knowledge Areas for Biological and Agricultural Engineering Students Labeled 'a' through 'at'.

Label	**Learning Outcome**
a	Given any two parameters (e.g. temperature, humidity, enthalpy, etc.), determine all other parameters in moist air.
b	Determine the flow rate of incompressible fluid in a pipe or duct accounting for all friction and head losses. Estimate the energy required to maintain this flow.
c	Determine steady-state and transient heat transfer via conduction, convection, and radiation.
d	Determine the unique aspects in the physical properties of food and biological materials and describe their importance to specific applications
e	Prepare a systems diagram of processes identifying all inputs, outputs, and external factors affecting the system.
f	Understand how food is produced.
g	Perform an energy balance on a system and determine efficiency.
h	Exhibit a general knowledge of machines and agricultural machinery.
i	Design machine components
j	Select appropriate materials for designing machine components.
k	Identify and discuss air quality factors related to agricultural production and processing.
l	Size and select a cyclone system to remove particulates from air
m	Design a filter system remove particulate matter from air

n	Design convenience systems to control runoff and drainage from watersheds.
o	Understand agricultural classification of soils.
p	Understand generation, transport, and fate of water.
q	Understand the processes involved in, damages caused by, and remediating measures that can be taken regarding wind erosion.
r	Size a pump and piping system and select the components. Calculate energy demand
s	Size a fan and duct system and select the components. Calculate the energy demand.
t	Size a drying system and select the components. Calculate the energy demand.
u	Design a material handling system for applications in food and agriculture
	1. Design a pneumatic conveying system and select the components. Calculate the energy demand.
	2. Design a belt conveyor and select the components. Determine the energy demand.
	3. Design an auger conveyor and select the components. Determine the energy demand.
v	Drying processes
	1. Calculate the amount of moisture removed from a biological product through drying.
	2. Evaluate the effects of process on product quality (air velocity, product properties.
	3. Drying curves.
	4. Spray drying
w	Thermal processes – heating, chilling, freezing and thawing
	1. Calculate the energy required to heat, cool, freeze or thaw biological materials.
	2. Select components
x	Design a thermal process system to sterilize a food product
	1. Canning
	2. Pasteurization
y	Non thermal processes for decontamination/disinfestation
	1. Irradiation
	2. UV
	3. Ozone
	4. High Pulse Electric Fields
	5. High Pressure
z	Select components for a food processing line (unit operations)
aa	Design a bioreactor
	1. Continuous stir tank reactor
	2. Batch reactors
ab	Design a disinfection system for wastewater
ac	Design a system for solid-liquid separations
	1. Design sedimentation system
	2. Design a filtration system
ad	Design a remediation system for nutrients and microorganisms.
	1. Fate and transport of chemicals and microorganisms
ae	Design small channels for drainage, irrigation and storm water management.
af	Design small impoundments for water supply, storm water management.
ag	Estimate erosion/sedimentation from small watersheds and apply appropriate BMPs.
ah	Estimate runoff volumes for pre- and post-development (land-use change).
ai	Determine soil water deficits at the watershed scale.
aj	Determine groundwater flow using well measurements (piezometers).
ak	Determine the boundaries of any watershed given an outlet point.
al	Determine pipe networks and pumping needs for simple water distribution systems.

am	Understand the concept of biomass.
an	Understand biochemical conversion to liquid fuels.
ao	Design and operate a thermal gasification or pyrolysis system.
ap	Design a logistics system to deliver harvested biomass to the processing facility.
aq	Design a sensing system to measure environmental variables.
ar	Design a system to control a process.
as	Design a small robot.
at	Understand, use, and troubleshoot agricultural and industrial electrical systems.

Ranking specific knowledge areas and learning outcomes

Specific knowledge areas (KAs) were compiled by faculty within the department and then ranked according to frequency as described here. Every KA presented in the original list from the faculty was placed in a list on excel. Next, KAs which covered similar themes were grouped together into one KA in order to condense the list. Each time a KA appeared as a requirement to proficiently accomplish the LO, they were tallied together and ordered according to frequency of appearance from greatest to least. Since every KA is required to perform some LO within the program, the KAs that appeared more than twice were considered essential for all BAE students. KAs that only appeared one time were specialized areas and were found to correlate mainly to the concentration. Each learning outcome was aligned with the KA as noted above. If a KA had a frequency of 9, that meant there were 9 LOs which correlated to that KA. By ranking the KA and their associated LOs, we were able to identify which KAs are most often used in the disciplines core curricula.

Results & Discussion

The investigative questions that were used to guide this research project were designed to allow us to identify key knowledge, skills and abilities graduates of a Bio-based engineering program possess. This was done with the understanding that graduates from the program have a common training through their core courses, before venturing into a concentration which further shapes the abilities of that student. Table 2 shows the LOs grouped to the four different concentrations and core processes in the BAE program at this University. The core processes are LOs which cross multiple concentrations and are integrated into the curriculum at an early stage. Although LOs should represent general knowledge, skills and abilities that all BAE students possess, they can still be characterized under a particular concentration. This goes along with the diverse training of a BA engineering graduate and helps us understand how they are so well versed in many areas of the discipline.

Table 2. List of Biological and Agricultural Engineering Concentrations and the associated learning outcomes (a – at).

Learning Outcomes	Concentration
a-f	Core Processes
g-j; aq-at	Power & Machinery – Design of Ag Systems, Machinery, and Processes; Electrical Systems
k-q; ae-al	Soil & Water – Water/Soil/Air Conservation and Quality; Soil and Water Engineering
r-ad	Post-Harvest Processing/Food Engineering/Bioprocess Engineering – Unit Operations in Food and Agriculture, Biology and Biological Processes
am-ap	Renewable Energy - Bioenergy

The concentrations listed in Table 1 represent the common emphasis areas, and the underlined title is used to represent the more descriptive concentrations listed thereafter. As previously noted, multiple LOs may require one particular KA. This is confirmed in Table 3, KAs with multiple LOs also cross different concentrations.

Table 3 shows each specific knowledge area and the number of LOs where it is required. Learning outcomes crossed multiple KAs for each specific concentration, meaning that a LO requires multiple skills in order to demonstrate proficiency of that outcome. The highest ranked KAs were (1) fluid mechanics, (2) heat and mass transfer and (3) physical properties of biological materials, each with 9 learning outcomes (Table 3). When examining the average BAE student, the knowledge they possess should correlate to the ranking of the KAs in the table; the greater the frequency the greater the likelihood that students are proficient in that area. When identifying which courses are commonly associated with BAE majors and the frequency in which they show up in curricula, Kaleita & Raman [2] found that *engineering properties of biological materials* was one of the only discipline specific courses which showed up more than 50% of the time. Other courses which showed up more than 50% of the time tend to be common engineering courses, regardless of the discipline. This correlates to the history and development of the discipline, Johnson [16] list the book *Biological Process Engineering: An Analogical Approach to Fluid Flow, Heat Transfer, and Mass Transfer Applied to Biological Systems* as a key textbook when the field of Agricultural Engineering was emerging. Two of the top three specific knowledge areas are key concepts of the book Johnson [16] highlights. Higher rankings identify the KAs which correspond to the most LOs, the top rankings help define a BAE student, without respect to their concentration. The higher rankings can be used to compare the emphasis of these specific knowledge areas across university BAE programs, to identify similarities and differences. Likewise, the ranked knowledge areas in Table 3 can be used to inform surveys of potential employers of BAE graduates.

Table 3. List of specific knowledge areas ranked according to the frequency (Freq) of occurrence for learning outcomes.

Rank	Specific Knowledge Area	Freq	Learning Outcome
1	Fluid mechanics	9	b l r s u z ac ae al
1	Heat and mass transfer (not mass balance), thermal props, Fundamentals of energy transfer	9	c d t v w x z aa y
1	Physical properties of biological materials (prediction and measurement), Materials testing & handling (raw materials through storage including packaging), Mixing-bulk fluid transport, moisture content & water activity	9	d j t v x w z aa
4	Psychrometrics	6	a l m t u v
4	Soil science, soil texture classification, soil structure, soil mineralogy, soil chemistry, Stoichiometry	6	o aa ae ag ai
4	Kinetics, Reaction kinetics, Factors affecting food quality, Microbial kinetics – thermal destruction	6	aa ab ad x
7	Hydrology	5	n p af ah ai aj
7	Basic control theory, controllers, Basic electricity, Computer programming, measurement science, sensors and transducers, Process control	5	z aa ar at aq
9	Microbiology	4	y aa ab
9	Inorganic chemistry, mass balance, heat and mass transfer, thermal conversion of materials, Fate processes: advection, dispersion, decay, growth, Metabolic pathways and bioenergetics	4	ao aa ad
9	Crop production, harvest, transport, Plant and animal materials from dedicated cultivation and process waste (BIOMASS), Simple machines, kinematics, agricultural field processes, agricultural machinery, Refrigeration cycle	4	f h w am
12	Logistics modeling, engineering economy, process economics	2	ap aa
12	Design principles, stress/strain/deflection, hand drafting, CAD, FEM, standards, safety, engineer's code of ethics, Stress/strain/hardness/ductility of metals and alloys, composites, aggregates, and polymers.	2	I j
14	Aeration	1	aa
14	Air quality regulation	1	k
14	Cleaning and sanitation	1	z
14	Wind erosion, control practices	1	q
14	Esterification, etc.	1	an
14	GIS	1	ak

The lower ranked knowledge areas in Table 3 are specific only to one learning outcome, as noted by the frequency column. These KAs are important for each BAE student to possess. As students matriculate through additional courses to train them in their concentration they will draw background knowledge from these KAs. Brumm et al. [9] mapped outcomes to individual classes to determine which competencies are addressed in a particular course. This work will likewise map courses to the learning outcomes to gain insight into how well the specific knowledge areas are addressed in the curricula.

Learning Outcomes, KAs and concentrations

Further examination of Table 3 shows the specific knowledge area which intersects the most concentrations is the one centered around '*crop production, harvest, transport, biomass… refrigeration cycle*'. This KA covers four LOs across three concentrations and core processes as defined in Table 2. This KA also maps to one of the learning outcomes found in the list in Table 4, *w – thermal processes*. Table 4 comes from the data presented in the Table 3 ranking, showing the LOs which require the most KAs. The LO which required the most KAs was *aa – design a bioreactor*, that meant this was one of the most complex and integrated LOs in the discipline. It involved 11 KAs and fit under post-harvest processing/food engineering/bio-process engineering (PH/FE/BE) concentration (Table 4). The PH/FE/BE concentration fit in 10 of the top 14 most intensive LOs, followed by Soil & Water then Power & Machinery. The intensity correlates to the number of KAs required to successfully accomplish the LO. The more knowledge areas required to complete a learning outcome correlate to the importance of the learning outcome. If we expect our students to possess higher level understanding of most of the knowledge areas then we assume that if provided with an assessment to complete the learning outcome they will be able to handle all or most of the outcome.

Table 4. Learning outcomes mapped to quantity of knowledge areas required and the corresponding concentration.

Learning Outcome	Number of Knowledge Areas	Concentrations
aa – design a bioreactor	11	PH/FE/BE
v – drying processes	5	PH/FE/BE
z – select components for food processing line	5	PH/FE/BE
x – design thermal process system to sterilize a food product	4	PH/FE/BE
t – size a drying system and select the components. Calculate energy demand	3	PH/FE/BE
w – thermal processes – heating, chilling, freezing and thawing	3	PH/FE/BE
j – select appropriate materials for designing machine components	2	PH/FE/BE
l – size and select a cyclone system to remove particles from air	2	Power & Machinery
u – design a material handling system for applications in food and agriculture	2	Soil & Water
y – non-thermal processes for decontamination	2	PH/FE/BE
ab – design a disinfection system for wastewater	2	PH/FE/BE
ad – design a remediation system for nutrients and microorganisms	2	PH/FE/BE
ae – design small channels for drainage, irrigation, and storm water management	2	Soil & Water
ai – determine soil water deficits at the watershed scale	2	Soil & Water

Learning outcomes which were under the emphasis area of renewable energy did not show up in the top 14 listed in Table 4. One explanation is that the emphasis area was not sufficiently covered when assigning knowledge areas to LOs. A larger scale survey to include a broader spectrum of faculty within the discipline will be distributed in the future to address this potential gap. Since PH/FE/BE as a concentration showed up most frequently in the list of LOs deemed important to BA engineers, this may be an area the discipline focuses on when describing this program. This concentration seems to correlate to the basis of the major, Young [9] found that the Agricultural Engineering curriculum was heavily aligned with chemical engineering when it comes to life science courses, and still holds true to key engineering topics, beyond that of a medical based bio-type engineering course. In order to differentiate chemical engineering and environmental engineering from BAE we had to identify learning outcomes and specific knowledge areas unique to the field. By ranking these knowledge areas and correlating them back to the learning outcomes we have identified connections which are unique to BAE students.

Conclusions

Engineering has been innovating advances in the agricultural and biological sectors for hundreds of years. The formation of engineers in this field will continue to play a helpful role in this advancement. The challenges faced in forming Biological and Agricultural Engineers includes variations in programs across universities and clearly defined learning outcomes and specific knowledge areas. Through this work, it was determined that the KA which mapped across the most concentrations was '*crop production, harvest, transport, biomass….refrigeration cycle*'. This points to what knowledge, skills and abilities are important for BAE students. Likewise, the KAs which appeared most frequently as requirements for the learning outcomes were (1) fluid mechanics, (2) heat and mass transfer and (3) physical properties of biological materials. Lastly, the learning outcome which required the most knowledge areas was for students to be able to *design a bioreactor*. Post-harvest processing/food engineering/bioprocess engineering as a concentration correlated to the most knowledge areas, defining it as an area where training of BAE students at this institution is centered. As we explore other universities there may be slight differences in the focus of the concentration. Future work will help develop a holistic evaluation of the learning outcomes, knowledge areas and concentrations to ensure they truly align with our expectations and explanations of the field as a whole.

This work will be used to inform our surveys for faculty concerning the knowledge level of each LO students must possess for their courses. Future results will show if there is a gap in expectations of LOs, and if we have LOs which students should possess but are never being exposed to in core courses within the curriculum. Likewise, this work will provide information, to be used in developing a survey to potential employers of the program's graduates, to determine if these LOs meet the employers' expectations and needs. These results will allow us to develop an all-inclusive description of the major, increasing visibility of the BAE discipline and employability of BAE graduates.

References

[1] H. C. Dethloff, S. W. Searcy, *Engineering Agriculture at Texas A&M: The First Hundred Years*. College Station, TX: Texas A&M University Press, 2015.

[2] A. L. Kaleita, and D. R. Raman, “A rose by any other name: an analysis of agricultural and biological engineering undergraduate curricula,” *Transactions of the ASABE*, 55(6), 2371-2378, 2012.

[3] ASABE, *American Society of Agricultural and Biological Engineers*, 2018. [Online]. Available: http://www.asabe.org/about-us/about-the-profession/abe-defined.aspx. [Accessed Jan. 8, 2018].

[4] A. T. Johnson and W. M. Phillips, “Philosophical foundations of biological engineering,” *Journal of Engineering Education*, 84, 311-318, 1995.

[5] F. Hafferty, C. C. Havighurst, and E. Freidson, “Books: Review Symposium on Eliot Freidson's Professionalism: The Third Logic,” *Journal Of Health Politics, Policy & Law*, 28(1), 133, 2003.

[6] R. Morsi, W. Ibrahim, and F. Williams, *Concept maps: Development and validation of engineering curricula*: Session T3H. 37th ASEE/IEEE Frontiers in Education Conference, October 10-13, 2007, Milwaukee, WI.

[7] M. Navarro, T. Foutz, S. Thompson, and K. P. Singer, “Development of a pedagogical model to help engineering faculty design interdisciplinary curricula,” *International Journal of Teaching and Learning in Higher Education*, 28, 3, 372-384, 2016.

[8] A. T. Johnson, H. Montas, A. Shirmohammadi, and F. W. Wheaton, “Change is necessary in a biological engineering curriculum,” *Biotechnol. Prog.*, 22, 167-172, 2006.

[9] T. J. Brumm, S. K. Mickelson, B. L. Steward, and A. L. Kaleita, “Competency-based outcomes assessment for agricultural engineering programs,” *Iowa State Repository, Digital Repository*. *Agricultural and Biosystems Engineering Publications*. 2006. [Online]. Available: http://lib.dr.iastate.edu/abe_engr_pubs_13. [Accessed Dec. 14, 2017].

[10] R. Young, “Comparisons of ‘Bio’-type engineering undergraduate curricula from agricultural, medical and chemical origins,” *International Journal of Engineering Education*, 22, 1, 14-22, 2006.

[11] L. Opara, and J. Cuello, “Transformation and Reinvention of Agricultural Engineering Education,” in *Int. J. Engng Ed.,* Vol. 22, No. 1, p. 2, 2006. [Online]. Available: https://www.ijee.ie/articles/Vol22-1/00d_G-Editorial.pdf. [Accessed Dec. 14, 2017].

[12] V. K. Lohani, M. L. Wolfe, T. Wildman, K. Mallikarjunan, and J. Connor, “Reformulating General Engineering and Biological Systems Engineering Programs at Virginia Tech,” *Advances In Engineering Education*, 2(4), 2011.

[13] S. Michelsen, A. Vabo, H. Kvilhaugsvik, and E. Kvam, “Higher education learning outcomes and their ambiguous relationship to disciplines and professions,” *Eur J Educ.*, 52:56-67, 2017. https://doi.org/10.1111/ejed.

[14] L. Meda, and A. J. Swart, “Analysing learning outcomes in an electrical engineering curriculum using illustrative verbs derived from bloom’s taxonomy,” *European Journal of Engineering Education*, 0, 1-14, 2017. [Online]. Available: https://doi.org/10.1080/03043797.2017.1378169. [Accessed Feb. 3, 2018].

[15] University of Toronto, “Developing Learning Outcomes: A Guide for University of Toronto Faculty.” Accessed 13 June 2016. [Online]. Available: http://teaching.utoronto.ca/wp-content/uploads/2015/08/Developing-Learning-Outcomes-Guide-Aug-121992014.pdf. [Accessed Jan. 8, 2018].

[16] A. T. Johnson, “Biological Engineering: What it means to me,” *ASABE Resource*, 19(4): 14-15, July/August 2012.