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New and Emerging Technologies: Teacher Needs, Adoption, Methods, and Student Engagement

Loren G. King[1], Aaron J. McKim[2], Matt R. Raven[3], and Catlin M. Pauley[4]

Abstract

Inclusion of new and emerging technologies within agriculture, food, and natural resources education curricula is essential to empowering learners for future success. In the field of Agriculture, Food, and Natural Resources (AFNR) Education, however, scant literature exists exploring teacher adoption of new and emerging technologies within their curriculum. In the absence of such research, AFNR Education is left to wonder if interventions are needed to increase the currency of AFNR curricula. Grounded in Diffusion of Innovations Theory, the current study sought to address this challenge in Michigan by analyzing teacher perceived needs, curricular implementation, teaching methods, and student engagement associated with 15 new and emerging AFNR technologies. Teachers perceived the highest needs related to teaching blockchain technology, unmanned aerial vehicles, and precision agriculture sensors. The most commonly taught technologies were genetic modification, value-added processes, and precision agriculture sensors. Across the 15 technologies, lecture was identified as the most common teaching method. Teachers reported student engagement was higher than average when teaching 11 of the 15 new and emerging technologies. In total, findings indicate clear opportunities to increase coverage of new and emerging AFNR technologies in Michigan. Further, the Diffusion of Innovations Theory offers insights into structuring interventions to increase curricular inclusion.

***Keywords*:** diffusion of innovations; emerging technologies; teacher awareness; student engagement; professional development needs

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Introduction

Agriculture, food, and natural resources (AFNR) systems are shifting in method and design at an unprecedented rate (Dennis, Aguilera, & Satin, 2009). The adoption of technology into production, sales, and management has dramatically affected the way food is produced and will continue to change as new technologies are adopted. Adoption of new technology sparks growth in labor productivity, incomes, and food security (Maertens & Barrett, 2013); additionally, new technologies bring the need for a generation with knowledge and skills related to these technologies (National Academies of Sciences, Engineering, and Medicine, 2018). AFNR Educators are positioned to provide knowledge of AFNR technologies to their students (Coley, Warner, Stair, Flower, & Croom, 2015; Lindner,

[1] Loren G. King is a senior studying Agriculture, Food, and Natural Resources Education at Michigan State University, 480 Wilson Road Room 131, East Lansing, MI 48824, kinglor1@msu.edu
[2] Aaron J. McKim is an Assistant Professor in the Department of Community Sustainability at Michigan State University, 480 Wilson Road Room 131, East Lansing, MI 48824, amckim@msu.edu
[3] Matt R. Raven is a Professor in the Department of Community Sustainability at Michigan State University, 480 Wilson Road Room 310A, East Lansing, MI 48824, mraven@msu.edu
[4] Catlin Pauley is a Technology Pathways and Agriculture teacher at Granville Jr./Sr. High School, 58 Quaker Street, Granville, NY 12832, cpauley@granvillecsd.org

Rodriguez, Strong, Jones, & Layfield, 2016), but the question emerges- are AFNR Educators implementing curriculum on the technologies considered the future of AFNR? Further questions arise, namely if technology is being taught, are students engaged in learning the content and, if so, are students able to apply their knowledge outside the classroom?

The current study seeks to understand the professional development needs and application of 15 new and emerging AFNR technologies within school-based agricultural education classrooms in Michigan and the engagement of students while learning the technologies. Furthermore, the current study seeks to understand what methods are being employed to teach new and emerging AFNR technologies. Identifying needs, methods, and student engagement related to teaching new and emerging AFNR technologies will provide a foundation upon which to expand coverage of these technologies throughout AFNR Education classrooms, preparing a generation of learners with knowledge and skill related to new and emerging AFNR technologies.

Theoretical Framework

Teaching new and emerging AFNR technologies represents a change in traditional curricula. In order to understand adoption of this curricular change, the current study is framed using the Diffusion of Innovations Theory (Rogers, 2003), a common theory for understanding adoption of changes within social systems, including AFNR Education (e.g., Murphrey & Dooley, 2000; Murphrey, Miller, & Roberts, 2009; Roberts, Harlin, Murphrey, & Dooley, 2007). In this theory, it is conceptualized that innovations (i.e., new ideas, practices, or objects) are "communicated through certain channels over time among members of a social system" (Rogers, 2003, p. 11). As individuals within a social system encounter an innovation, they undergo an innovation-decision process which includes (a) awareness and knowledge of the innovation, (b) positive or negative attitude formation, (c) decision to adopt or reject the innovation, (d) implementation of the innovation, and (e) confirmation of the implementation decision (Rogers, 2003). Of importance within the Diffusion of Innovations Theory are the attributes of the innovation as well as the attributes of the adopters. With regard to the innovation, Rogers (2003) identified innovations as more likely to be adopted when the innovation represents an advantage to existing ideas, practices, or objectives; is compatible with existing norms and needs; is easier to use; is more easily experimented with; and produces results visible to others. Additionally, Rogers (2003) identified five categories of adopters ranging from innovators (i.e., first to adopt) who take risks and develop new ideas to laggards who, due to being bound by tradition, are the last to adopt new technologies; other categories on this continuum include early adopters, early majority, and late majority.

The current study operationalized the Diffusion of Innovations Theory by exploring teacher competence (i.e., evaluation of awareness and knowledge) and value (i.e., evaluation of attitude formation) of 15 new and emerging AFNR technologies via a needs assessment. Further, adoption decisions were evaluated as teachers reported if and, if so, how the new and emerging technologies were taught within their curriculum, information illuminating the adaptor categories (e.g., innovators, laggards) of Michigan AFNR teachers. Finally, teacher-reported student engagement while being taught the new and emerging AFNR technologies was analyzed to represent an element of the decision confirmation, assuming teachers continue to teach curriculum which engages their students.

Literature Review

New and Emerging Technologies

One of the only constants in the AFNR systems is change. The rate of technological innovation throughout AFNR, especially over the past 60 years, is staggering (Dennis et al., 2009). Technological evolutions have shifted AFNR systems from resource-based to science-based, rebranding AFNR as a high technology field (Allmaras, Wilkins, Burnside, & Mulla, 2018). The accelerated adoption of new technologies throughout AFNR can be attributed to increases in research, production, marketing, and knowledge access (Allmaras et al., 2018). To remain a valuable educational pathway to careers in science-based AFNR, secondary school AFNR Education must stay abreast to emergent trends and technologies. The current study provides the first known empirical study of teacher utilization of new and emerging technologies (i.e., listed and described within the methods) within AFNR. The information gained will suggest the alignment between AFNR Education in Michigan and emerging technologies in AFNR. Acquisition of this knowledge will inform stakeholders to AFNR Education of the need for resources to update the learning experiences offered within Michigan AFNR Education to match emergent trends in the industry.

Methods for Teaching Technology

Teaching science, technology, engineering, and mathematics (STEM) in AFNR Education is critically important to developing the next generation of professionals in AFNR systems (Scherer, McKim, Wang, DiBenedetto, & Robinson, 2019). Amongst STEM concepts, technology and engineering receive the least attention in AFNR Education practice and research (Scherer et al., 2019). Existing literature suggests when STEM concepts are taught in AFNR classrooms, specific technologies are rarely the focus (Wang & Knobloch, 2018). Similarly, Smith, Rayfield, and McKim (2015) found teacher confidence teaching technology and engineering was lower than teaching science and mathematics. In a study of Alabama teachers, the integration of new and emerging AFNR technologies within curricula was identified as the area of highest need perceived among respondents (Clemons, Heidenrich, & Lindner, 2018). In total, existing research articulates the importance of STEM within AFNR Education while simultaneously identifying a lack of emphasis and high perceived need for professional development related to teaching new and emerging AFNR technologies. The current study seeks to take the next step in understanding this phenomenon by identifying perceived needs related to 15 specific new and emerging AFNR technologies along with evidence of teacher adoption and subsequent student engagement to justify expanded technology education within secondary school AFNR classrooms.

Student Engagement

Teaching and learning is a reciprocal relationship which includes selection of material, selection of method, and student engagement. Therefore, analyzing the adoption of new and emerging AFNR technologies from a curricular implementation and method selection perspective is incomplete without considering student engagement. Research suggests student engagement consists of cognitive engagement, behavioral engagement, and emotional engagement (Friedel & Anderson II, 2017). Specific to the classroom domain, Friedel and Anderson II (2017) found positive relationships between student engagement, field trips, homework, contacting experts, and written assignments. Applying skills in the laboratory, on the other hand, was negatively related to all three elements of student engagement (i.e., cognitive, behavioral, and emotional). Stepping outside the focus on teaching methods, Bird, Martin, Tummons, and Ball (2013) found the teacher-student relationship to be most important to student engagement within secondary school AFNR Education classrooms. Existing research suggests student engagement is a multi-faceted construct influenced by relationships and content. In the current study, we seek to expand current understanding of instruction and student engagement in new and emerging AFNR technologies in AFNR Education curricula by exploring student engagement levels during instruction of content related to new and emerging AFNR technologies.

Purpose and Objectives

The National Research Agenda priority area two identifies a need for research exploring the adoption decisions of new technologies, practices, and products (Lindner et al., 2016). In AFNR Education, this can be operationalized as teachers educating students in the technologies relevant to the future. To address this identified need, the purpose of the current study is to explore current needs and adoption of new and emerging AFNR technologies within the curriculum taught by Michigan AFNR teachers. The research purpose is achieved via the following objectives: (a) identify the perceived needs of Michigan AFNR teachers related to new and emerging AFNR technologies; (b) identify the new and emerging AFNR technologies being taught in Michigan AFNR classrooms; (c) identify the methods used to teach new and emerging AFNR technologies within Michigan AFNR classrooms; and (d) describe the perceived student engagement when new and emerging technologies are being taught in Michigan AFNR classrooms.

Methods

The population for the current study included all secondary school-based AFNR teachers in Michigan (N = 131) during the 2018-2019 school year. Contact information was obtained from the Michigan Agriscience Teacher Directory and was vetted for accuracy by the state director for AFNR Education.

Data Collection and Response Rate

A census was attempted of all secondary school-based AFNR teachers in Michigan. Data were collected from September to October of 2018 using the online survey program Qualtrics. Three points of contact were used to gather responses from participants. The first two points of contact were made through an email invitation from the authors of the study. The final point of contact was an email invitation from the Michigan director for AFNR Education. A total of 47 (n = 47) AFNR teachers responded, yielding a 35.88% response rate. Given the small sample size, findings are not inferred beyond respondents; therefore, non-response bias was not evaluated and inferential statistics were not used.

Instrumentation

The survey instrument included five sections, (a) needs assessment, (b) curricular inclusion, (c) methods of teaching, (d) student engagement, and (e) demographics. Within the needs assessment, 15 new and emerging AFNR technologies were described (see Table 1) and respondents rated the importance of each of the technologies as well as their competence teaching the new and emerging AFNR technologies. Both importance and competence were rated from 1 (*Very Low*) to 5 (*Very High*). The 15 new and emerging technologies included in the survey were chosen via a panel of five experts with diverse backgrounds in AFNR industries. The panel was tasked with identifying the 15 technologies which have the most potential to change AFNR over the next 25 years.

Table 1

New and Emerging AFNR Technologies and Description

AFNR Technology	Description
5G Internet	The 5th generation in wireless technology. It is expected to greatly increase the ability of devices to communicate and expand internet coverage into rural areas.
Blockchain Technology	Blockchain technology is a record keeping system. It can be used for tasks, trading, or sales. The system is secure from potential hacking and provides instant results. It also only happens between the buyer and seller, without involving a bank or other third party.
Closed Ecological Systems	Ecosystems that do not rely on matter exchange with any part outside the system. In a closed ecological system, any waste products produced must go back into the system itself. This can be seen in environmental management practices or in farms that use animal herd waste to fertilize crops fed back to the animal herd.
Cultured/In-Vitro Meat	Meat produced using animal cells cultured in a laboratory rather than in the use of animal products. Known as a form of cellular agriculture, in vitro meat uses tissue regeneration.
Digital Twinning	The use of computer models to replicate a physical object. In agriculture, this can refer to using models of fields to predict future growth patterns, or data from machinery to predict possible failure of equipment.
Farm Management Apps	Digital applications on cell phones or computers that provide a specific agricultural utility. Applications can range from fertilizer rate application calculators to farm machinery locators.
Genetic Modification	The insertion of genes from other organisms to increase water use efficiency, protect against pests, or reduce bruising. Modern methods also include CRISPR, which can modify genes through computer programs without using the genetics of other organisms.
Livestock Biometrics	Measurable indicators that show animal health and can be recorded. Measurement systems can include RFID tagging or similar sensor methods. Livestock biometrics can be used to recommend changes to feed or recognize potential animal illness.
Precision Agriculture Sensors	Sensors collecting and recording data about air, soil, crop, infrastructure health, and animal management. The basis for precision agriculture, sensors can be applied to nearly every aspect of the agricultural industry.
Rapid Iterative Selective Breeding (RISB)	Considered the next generation in selective breeding, RISB uses algorithms to suggest improvements. The end-result of a breeding is analyzed quantitatively through computer programs before recommendations are made. Allows for efficiency increases in the pursuit of desired breed traits.

Table 1

New and Emerging AFNR Technologies and Description Continued…

Satellite Imaging	The use of images from satellites for insight into field health or environmental impacts. Satellite images can either be retrieved from free open sources, such as Google Earth, or farmers can contract specialized images from companies. Satellite images over many years can show trends in impact or be used to predict future change.
Synthetic Biology	The artificial design and engineering of biological systems and living organisms for purposes of improving applications for industry or biological research. Can involve the creation of new enzymes for waste processing or similar modifications to increase efficiency.
Unmanned Aerial Vehicles (UAVs)	Commonly known as drones, UAVs can be operated on a farm to gain up-to-date images of a field without needing satellite imaging. Drones can also be equipped with cameras to record vegetation indexes or show environmental damage to fields after storms.
Value-Added Processes	The expansion of farm activities to include operations beyond traditional crop or animal production. This can include ethanol refining, agrotourism, milk pasteurization, or any other process or creation from farm products that normally happens beyond the farm gate.
Vertical Farming	Raising crops in a building either through rooftop gardening, soil-based production, or using hydroponics/aeroponics. Vertical farming is used to reduce miles traveled for food and increase access to fresh produce within urban areas. Vertical farming often requires little to no pesticide application and often uses technology, such as variable lighting.

The curricular inclusion section included a list of the 15 new and emerging AFNR technologies in which respondents indicated if they had taught each of the technologies within their curriculum, either yes or no. The methods of teaching and student engagement sections were individualized to each of the 15 new and emerging technologies and only made available to respondents who indicated "yes" to teaching the selected technologies. For methods of teaching, respondents indicated which methods they used to teach the new and emerging technology from a list that included brainstorming, lecture, discussion, paired or small group discussion, role play, demonstration, case study, field trip, resource people, experiment, games and simulations, supervised study, and debate (list derived from Phipps, Osborne, Dyer, & Ball, 2008). For the student engagement section, respondents were asked to rate student engagement while learning the new and emerging technology from 0 (*Extremely Low*) to 100 (*Extremely High*), with 50 (*Average*) representing average student engagement during lessons facilitated by the respondent. The final section of the instrument included demographic variables, identified in the description of respondents.

A panel of experts in AFNR education examined the instrument and established content and face validity for the different sections. None of the data are reported as constructs, therefore, construct reliability is not reported.

Data Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS). Needs assessment data were analyzed by identifying the mean weighted discrepancy score (MWDS) which is determined by the discrepancy between perceived importance and competence for each new and emerging AFNR technology weighted by average importance (Borich, 1980). Curricular inclusion is reported as the percentage of responding teachers who had taught the new and emerging technology within their curriculum. Student engagement is reported as the average student engagement score reported by those teachers who had taught the curriculum. Methods of teaching are reported as the most common teaching method used by teachers who had taught the new and emerging technologies, along with the percentage of teachers who utilized the most common methodology.

Description of Respondents

Respondents included slightly more female (56.70%) than male (43.30%) AFNR teachers with an average age of 42.34 years. The most common level of education reported among respondents was Master's Degree (66.60%) followed by Bachelor's Degree (29.90%) and Doctoral Degree (3.30%). The majority of respondents completed a traditional teacher education program in AFNR Education (60.00%) and taught in rural communities (63.30%) followed by suburban (30.00%) and urban (6.70%) communities. On average, responding AFNR teachers had 95.63 unduplicated students within their AFNR program. The demographics of respondents closely align with the known demographics of all Michigan AFNR teachers.

Findings

In research objective one, we sought to identify the perceived needs of Michigan AFNR teachers related to new and emerging AFNR technologies (see Table 2). Overall, teachers consistently rated the importance of the new and emerging technologies higher than their perceived competence teaching the material. Genetic modification was identified as the most important new and emerging technology provided (M = 4.06) followed by value-added processes (M = 3.97) and precision agriculture sensors (M = 3.94). With regard to competence, teachers perceived themselves most competent teaching value-added processes (M = 3.50) followed by vertical farming (M = 3.29) and genetic modification (M = 3.03).

Table 2

Perceived Needs of Michigan AFNR Teachers: New and Emerging AFNR Technologies

New and Emerging AFNR Technology	Perceived Importance	Perceived Competence	MWDS
Blockchain Technology	3.14	1.41	5.63
Unmanned Aerial Vehicles (UAVs)	3.74	2.29	5.61
Precision Agriculture Sensors	3.94	2.65	5.21
Farm Management Apps	3.85	2.59	5.05
Digital Twinning	3.21	1.78	4.82
Rapid Iterative Selective Breeding (RISB)	3.47	2.13	4.70
Genetic Modification	4.06	3.03	4.18
5G Internet	3.34	2.24	3.93
Synthetic Biology	3.34	2.29	3.77
Livestock Biometrics	3.78	2.84	3.66

Table 2

Perceived Needs of Michigan AFNR Teachers: New and Emerging AFNR Technologies Continued…

Satellite Imaging	3.64	2.88	2.84
Cultured/In-Vitro Meat	2.97	2.25	2.23
Closed Ecological Systems	3.55	2.97	2.22
Value-Added Processes	3.97	3.50	2.12
Vertical Farming	3.69	3.29	1.55

Note. Perceived importance and perceived competence (i.e., "Competence Teaching Subject") measured from 1 "Very Low" to 5 "Very High." MWDS indicate perceived need for professional development in selected areas, with higher scores relating to higher perceived needs.

Combining perceived importance and perceived competence yielded MWDS, a representation of the need for professional development within identified areas. Results indicate blockchain technology (*M* = 5.63) was the area of highest perceived need followed by unmanned aerial vehicles (*M* = 5.61) and precision agriculture sensors (*M* = 5.21). Alternatively, vertical farming (*M* = 1.55), value-added processes (*M* = 2.12), and closed ecological systems (*M* = 2.22) were identified as the three areas in which the lowest perceived needs were identified.

In research objective two, we sought to identify the new and emerging AFNR technologies being taught in Michigan AFNR classrooms (see Table 3). Of the responding teachers, over half indicated teaching four of the new and emerging technologies, including genetic modification (83.90%), value-added processes (77.40%), precision agriculture sensors (71.00%), and vertical farming (71.00%). Additionally, of the 15 new and emerging technologies included in the study, all but digital twinning were represented in at least one responding teacher's classroom.

Table 3

New and Emerging AFNR Technologies Utilization, Engagement, and Methods

New and Emerging AFNR Technology	Percent Teaching	Student Engagement	Most Common Teaching Method
Genetic Modification	83.90%	74.20	Lecture (76.92%)
Value-Added Processes	77.40%	73.71	Lecture (62.50%)
Precision Agriculture Sensors	71.00%	62.82	Lecture (77.27%)
Vertical Farming	71.00%	70.60	Lecture (77.27%)
Satellite Imaging	58.10%	69.56	Lecture (77.78%)
Farm Management Apps	48.40%	57.89	Lecture (60.00%)
Closed Ecological Systems	41.90%	64.40	Lecture (76.92%)
Cultured/In-Vitro Meat	38.70%	64.11	Lecture (83.33%)
Livestock Biometrics	38.70%	60.89	Lecture (50.00%)
Unmanned Aerial Vehicles	36.70%	72.33	Lecture & Demonstration (54.55%)

Table 3

New and Emerging AFNR Technologies Utilization, Engagement, and Methods Continued…

Rapid Iterative Selective Breeding	12.90%	36.00	Lecture (50.00%)
Synthetic Biology	9.70%	74.33	Lecture (100.00%)
5G Internet	3.20%	0.00	NA
Blockchain Technology	3.20%	0.00	Lecture (100.00%)
Digital Twinning	0.00%	NA	NA

Note. Percent teaching indicates the proportion of teachers who responded they had taught the new and emerging AFNR technology. For teachers who indicated teaching the technologies, student engagement was measured from 0 "Extremely Low" to 100 "Extremely High," with 50 representing "Average Student Engagement." In addition, teachers were asked which teaching method they used to teach the material, with the most common response (and percent who indicated using methodology) identified.

In research objective three, our focus shifted to student engagement (see Table 3). Specifically, we sought to describe perceived student engagement when new and emerging technologies are being taught in Michigan AFNR classrooms. In total, 11 out of the 15 new and emerging technologies yielded student engagement above the "average" level of student engagement among teachers who taught the identified AFNR technologies. The four falling below the average level of student engagement were rapid iterative selective breeding (M = 36.00), 5G internet (M = 0.00), blockchain technology (M = 0.00), and digital twinning (M = NA); however, the lack of teachers teaching this material minimize the credibility of these findings. The new and emerging technologies related to the highest levels of student engagement were synthetic biology (M = 74.33), genetic modification (M = 74.20), and value-added processes (M = 73.71).

In research objective four, we sought to identify the methods used to teach the new and emerging AFNR technologies within Michigan AFNR classrooms. Teaching methods were collected for teachers who indicated teaching the identified new and emerging technologies. The most common teaching method utilized was lecture. Across the new and emerging technologies, discussion (i.e., for genetic modification, value-added processes, satellite imaging, livestock biometrics [tie], rapid iterative selective breeding [tie], and synthetic biology) and demonstration (i.e., for precision agriculture systems, vertical farming, farm management apps, and livestock biometrics [tie]) followed lecture as the most common teaching methodologies with the exception of field trips being the second most common teaching method for closed ecological systems, debate being the second most common teaching method for cultured/in-vitro meat, and case study being tied as the second most common teaching method for livestock biometrics and rapid iterative selective breeding.

Conclusions and Discussion

The dynamic and ever-evolving nature of AFNR systems (Allmaras et al., 2018; Dennis et al., 2009) requires career-long learning and curricular adaptations among school-based AFNR teachers seeking to offer curriculum which prepares learners for future success. The ability of AFNR teachers to remain forward thinking with regard to the AFNR technologies they teach positions the system of AFNR Education to develop generations of learners prepared to be successful and continue the advancement of the field toward a more productive and sustainable tomorrow (Coley et al., 2015; Lindner et al., 2016; Scherer et al., 2019). However, curricular complacency in the form of teaching antiquated technologies fails to address the needs of learners, AFNR systems, and society. Scant literature exists exploring AFNR teacher utilization of new and emerging AFNR technologies (Wang & Knobloch, 2018). The current study sought to address this limitation by providing the first published research exploring AFNR teacher perceived needs, curricular inclusion, teaching methods, and student engagement concerning 15 new and emerging AFNR technologies. The information gained provides a foundation upon which to expand the inclusion of new and emerging AFNR technologies in Michigan and beyond.

In research objective one, perceived needs were explored using a needs assessment approach (Borich, 1980). The resultant MWDS illustrate the perceived needs of teachers, with higher scores representing a higher need for professional development. Among the top ten identified need areas, three feature technology directly interacting with biological aspects of AFNR (i.e., genetic modification, rapid iterative selective breeding, and synthetic biology). The remaining seven technologies are all focused on computer programs for data management or sensor-based technology for retrieving data from crops or livestock. These results indicate responding Michigan AFNR educators place high importance on data transfer technologies but are not prepared with regard to the content they provide in the classroom. Possible explanations include the cost of these technologies, which may be prohibitive to teachers (Coley et al., 2015). Additionally, teacher training may provide a conceptual foundation for biological-based technologies but not computer-based technologies, making computer-based technologies less accessible to responding AFNR educators. From the theoretical perspective, findings suggest computer-based technologies may lack the ease of adoption and experimentation characteristics of innovations in which teachers perceived less need (Rogers, 2003).

Continuing with perceived needs, the three lowest rankings were found for vertical farming, value-added processes, and closed ecological systems. These technologies can be classified as on-farm management methods or ways of thinking about the entirety of an operation. An understanding of these three technologies, and a smaller MWDS, could be due to the compatibility of the innovations with existing norms and needs, an advantageous characteristic of innovations (Rogers, 2003); specifically, the experience of AFNR educators in agri-business concepts and the potential of some educators to have close experience with AFNR operations. The two remaining technologies were satellite imaging and in-vitro meat. The widespread use of satellite imaging in certain sectors of AFNR systems, and visibility of results (Rogers, 2003), may have led to the relatively low perceived need, as materials on the topic are readily available. In comparison, in-vitro meat has become more important to AFNR systems in recent years, dramatically affecting the prospects of beef operations. Having received the lowest importance score from respondents and second lowest in competence, in-vitro meat appears to lack advantageous adoption characteristics. Inherent protection of the beef industry and desire to focus on traditional food production rather than synthetic production may have resulted in teachers feeling in-vitro meat is incompatible with existing norms and needs, making it less likely to be adopted as an innovation within AFNR curriculum (Rogers, 2003).

In research objectives two through four, curricular inclusion, methods of teaching, and student engagement were each evaluated. Results of the curricular inclusion assessment showcase only five of the 15 new and emerging AFNR technologies are being taught by the majority of respondents (i.e., genetic modification, value-added processes, precision agricultural sensors, vertical farming, and satellite imaging). Findings suggest a large proportion of new and emerging AFNR technologies are not being addressed in the majority of respondents' AFNR classrooms, which supports existing research suggesting a limited emphasis on technology integration within AFNR Education (Scherer et al., 2019; Wang & Knobloch, 2018). Additionally, findings illuminate those new and emerging AFNR technologies with adoption advantages (e.g., compatible with existing norms and needs, easy experimentation) to lesser-adopted technologies (Rogers, 2003). However, when evaluating student engagement, teachers reported above average student engagement when teaching 11 out of the 15 new and emerging AFNR technologies; thus, adopting teachers are more likely to perceive confirmation of their implementation decision (Rogers, 2003). Furthermore, positive student engagement belies an opportunity to expand the inclusion of new and emerging technologies in Michigan AFNR classrooms with early majority, late majority, and laggard-teachers with the expectation of high student engagement when these technologies are taught.

With regard to teaching methods utilized to teach new and emerging AFNR technologies, findings suggest a reliance on lecture. In fact, lecture was used by at least half of responding teachers who reported teaching the identified new and emerging technologies. Lecture has the advantage of covering large amounts of information in a short amount of time; however, does not adhere to the hands-on learning ethos of school-based AFNR Education (Phipps et al., 2008). Typically, lecture is not seen as an ideal teaching method; yet, the high student engagement scores suggest lecture as an effective tool to introduce new and emerging technologies. This is not trivial, as it provides a cost-effective and engaging entry-point for educators and learners regarding new and emerging technologies. While data in the study did not directly address cost as a factor, existing research indicates cost as a limiting factor to technology integration within the classroom (Coley et al., 2015). Therefore, lecture serves to introduce the new and emerging technologies while not requiring the school or program purchase the equipment. However, the prevalence of lecture raises a question of the depth of learning and, subsequently, student application outside of the classroom.

Recommendations

A number of recommendations for practice and research emerge from the findings and discussion of this research. To organize these recommendations, specific sections are delineated by recommendations for research and recommendations for practice.

Recommendations for Research

As an initial investigation into teacher needs, curricular inclusion, teaching methods, and student engagement, the current study was limited to respondents from one state. Further research around the country will help to demonstrate if the results within the study are state specific or geographically replicable. In addition to expanding the scope of research, we also recommend expanding the depth of research by collecting student responses on engagement while learning via multiple teaching methods to help inform educators wanting to select the most engaging methods for teaching new and emerging AFNR technologies. Additionally, a barrier-based assessment is also recommended. In this approach, scholars are encouraged to evaluate why late majority and laggard-teachers have not chosen to teach new and emerging technologies, seeking to understand if the technologies are cost prohibitive, considered hard to teach without knowledge on best methods, or simply unknown to the educator. Further, future research is recommended which explores the relationship between exposure to new and emerging technologies during teacher training experiences (e.g., formal academic training, professional development, collaborations, student teaching) and incorporation of new and emerging AFNR technologies within their curriculum. In parallel, research is needed to determine the effectiveness of the incorporation of these new and emerging technologies in terms of student learning. Finally, an investigation of AFNR career interests in relation to learning new and emerging AFNR technologies within secondary school AFNR classrooms could provide additional motivation to incorporate these technologies throughout AFNR Education.

Recommendations for Practice

One pragmatic benefit of a needs assessment is it offers a path forward for training programs to address the identified needs of teachers. Therefore, it is recommended that stakeholders in Michigan develop educational materials and training sessions for technologies in alignment with teacher-perceived needs. Additionally, teacher training should demonstrate how other methods in addition to lecture can be used for teaching new and emerging AFNR technologies. This focus could be nicely paired with a discussion of potential funding sources AFNR programs could leverage to purchase appropriate technologies (e.g., unmanned aerial vehicles, vertical farming equipment, precision agriculture sensors) to facilitate more hands-on and immersive learning experiences. In addition, teacher education programs are encouraged to evaluate student coursework to ensure opportunities to obtain a foundation of both biological-based and computer-based knowledge. Finally, recognizing the ever-changing nature of AFNR systems, a greater emphasis on learning how to learn throughout a career (e.g., selection of information sources, time management, professional development) must continue to be an emphasis throughout teacher education programs. In total, interventions should foreground the advantages of new and emerging AFNR technologies in accordance with the Diffusion of Innovations Theory (Rogers, 2003) while seeking to remove potential barriers to adoption.

Providing the highest quality learning experiences should be the goal of every AFNR educator. Quality has many interpretations; however, in AFNR Education a quality learning experience must be one which prepares learners for the future. To meet this definition, AFNR Education must stay apprised to the emerging trends and technologies found throughout AFNR systems. In this way, learners are not only exposed to those technologies which will be more commonplace as they continue throughout their careers, but introduced to the idea of AFNR systems being dynamic, technology-driven, science-based, and ever-changing.

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