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Sustainable Water Management within Agriculture, Food, and Natural Resources Education

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Abstract

Water scarcity is a global problem in which, through consumption and eutrophication of freshwater, agriculture has contributed. The impact of water scarcity necessitates research into how agriculture, food, and natural resources (AFNR) educators can support solutions. A subset of AFNR educators in the Great Lakes Basin participated in a professional development experience designed to introduce how online, sustainable water management tools could be incorporated within AFNR curricula. Participants were then surveyed about past and future intentions to incorporate the tools. Results indicated teachers planned to increase utilization of sustainable water management tools by 3.50 days per school year. Qualitative feedback suggested teachers planned to use the tools to achieve a variety of aims, including teaching about water usage, the relationship between soil and water, and record keeping. Participants were also asked to evaluate the alignment between sustainable water management tools and AFNR education. Teachers perceived the strongest alignment between sustainable water management tools and Environmental Services Systems and Natural Resources Systems pathways. Findings from this mixed-method study are discussed using the Model of Teacher Change, including recommendations for future professional development on sustainable water management and research on increasing the ability of AFNR educators to support water scarcity solutions.

Keywords: information technologies; professional development; school-based agricultural education; sustainable water management

Introduction

Agriculture, food, and natural resources (AFNR) educators hold a moral imperative to teach content and practices which solve, rather than contribute to, problems (Andenoro, Baker, Stedman, & Weeks, 2016). One of the most pressing problems today is water scarcity (Mancosu, Snyder, Kyriakakis, & Spano, 2015). The water scarcity problem is not temporary, as increases in climate change, global population, and food production further stress the system. The breadth of impact associated with water scarcity is significant, including up to two-thirds of the global population being negatively affected by 2045 (Mancosu et al., 2015). The significance of this problem necessitates AFNR educators consider their role in contributing to a water scarcity solution.

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A strong link exists between agriculture and water scarcity. Globally, agriculture is the largest consumer of water, accounting for approximately 70% of withdrawals (Mancosu et al., 2015). Furthermore, projected increases of 16% in irrigation water requirements (Fischer, Shah, Tubiello, & van Velhuizen, 2005) suggests agriculture's demand for water will only increase. In addition to demanding an overwhelming portion of available water, non-point source nutrient runoff from agriculture is a major contributor to eutrophication of freshwater, further straining social and environmental water systems (Kerr, DePinto, McGrath, Sowa, & Swinton, 2016; Michalak et al., 2013). The relationship between agriculture and freshwater is highlighted within analysis of the Great Lakes Basin. The Great Lakes Basin is home to approximately 21% of the world's surface freshwater (Environmental Protection Agency, 2017). Since reductions of restrictions in 2000, agricultural runoff has contributed to a re-eutrophication of the Great Lakes Basin (Fales et al., 2016; Kerr et al., 2016). In 2011, Lake Erie experienced a record-breaking algal bloom, which has been traced back, in part, to trends in agricultural practices (Michalak et al., 2013). The relationship between agriculture and water within the Great Lakes Basin is made more complex by the scope of production agriculture in the region, which totals 7% of American (i.e., $15 billion annually) and 25% of Canadian farm production (Kerr et al., 2016).

Recognizing the role of agriculture in the water scarcity problem, interventions like education in sustainable water management approaches have been recommended (Fales et al., 2016). In fact, research suggests educational interventions are effective at increasing the sustainability of water use practices (Suh, Khachatryan, Rihn, & Dukes, 2017). AFNR educators in high school settings are uniquely positioned to create change in the behaviors of students at an early age through education in sustainable water management. Furthermore, AFNR educators have an opportunity to present the complexity of the relationship between water scarcity and production agriculture, illuminating the interconnecting needs of food and water. Therefore, the current study explored how a subset of AFNR educators in the Great Lakes Basin envisioned application of online, sustainable water management tools (e.g., the Great Lakes Water Management System [GLWMS]) within their curricula after engaging in a professional development experience. Acquisition of this knowledge provides a foundation for how sustainable water management content and practices can be incorporated within AFNR curriculum, empowering AFNR educators to contribute to water scarcity solutions.

Literature Review

Three relevant themes were reviewed, providing a foundation of knowledge to which the current study contributes. Specifically, this review takes a deeper look into sustainable water management as well as brief analyses of teaching about water and effective professional development experiences.

Sustainable Water Management

Sustainable water management arose in response to increased awareness of water quantity and quality issues due to the misuse of water resources. As an approach, sustainable water management attends to "all practices that improve crop yield and minimize non-beneficial water losses" (Mancosu et al., 2015, p. 976). Within production agriculture, these practices include irrigation system choice, irrigation scheduling (i.e., timing and quantity), and soil and climate-based crop management decisions (Mancosu et al., 2015). Research suggests, however, due to limited local networking capacity, some producers are unaware of, or unwilling to participate in, sustainable water management (Fales et al., 2016). To address this reluctance, Fales et al. suggested "technical assistance in the form of outreach, education, conservation planning, and program sign-

up and administration are essential forms of support for producers and can greatly influence their participation in conservation programs" (2016, p. 1374).

Focusing on education as a means to support sustainable water management, introducing information technology tools which intuitively combine topographic, climatic, and soil data to support informed decision making has been effective (Fales et al., 2016). Therefore, the professional development intervention utilized within the current study leveraged information technology tools housed within the Institute of Water Research at Michigan State University, including the GLWMS, by introducing a subset of AFNR teachers to the tools, their application, and potential uses within AFNR curriculum.

Teaching about Water

The majority of work addressing water scarcity has sought technical solutions (e.g., efficient irrigation systems, drought resistant crops) without attending to the human factors critical to understanding, and providing solutions to, the water scarcity problem (Breukers, van Asseldonk, Bremmer, & Beekman, 2012). Mentions of the social component include recommendations for expanded educational efforts, without discussing *how* to facilitate such experiences (e.g., Fales et al., 2016). Recently, a flurry of research has started to address *how* to teach water conservation within an AFNR context (e.g., Huang & Lamm, 2015; Lamm, Lamm, & Carter, 2015; Lamm, Warner, Martin, White, & Fisher, 2017; Owens & Lamm, 2016, 2017). In consensus, studies highlight the importance of AFNR educators, regardless of position, in addressing water scarcity. However, challenges have been identified, including learners disassociating themselves from the problem (Delorme, Hagen, & Stout, 2010), the influence of political affiliation (Owens & Lamm, 2017), and disagreements between AFNR leaders and the general public (Lamm et al., 2015).

Acknowledging these challenges, five recommendations have emerged for teaching sustainable water management within AFNR, including (a) developing the knowledge and communication skills of AFNR opinion leaders regarding water management, (b) using common, non-technical language when discussing water issues, (c) creating educational coalitions with similar values related to water management, (d) teaching with rich descriptions and anecdotes connecting agriculture and water, and (e) utilizing flexible educational experiences, adaptable to the characteristics of the learners (Lamm et al., 2015). The current study adds to the burgeoning literature by exploring the impact of a professional development experience on school-based AFNR education teachers and their intentions to incorporate sustainable water management tools within their curricula.

Professional Development

The intervention in this study was a professional development experience addressing sustainable water management tools; therefore, a brief review of the literature on effective professional development experiences is included. Looking at the broad education literature, five elements of professional development have emerged as being critical to a successful experience, (a) focus on content knowledge, (b) opportunities for active learning, (c) coherence with other learning opportunities, (d) collective participation among teachers, and (e) sufficient duration (Garet, Porter, Desimone, Birman, & Yoon, 2001; Wilson, 2013). Research within school-based AFNR education supports the value of professional development experiences (Shoulders & Myers, 2014), including positive relationships between professional development and teacher self-efficacy (McKim & Velez, 2017; Stachler, Young, & Borr, 2013) as well as increased engagement in inquiry-related activities (Shoulders & Myers, 2014).

Research illuminating the effective characteristics of professional development experiences was used in the construction of the sustainable water management professional development experience discussed in the current study. Additionally, existing research in AFNR education suggesting positive outcomes associated with professional development provided the motivation to utilize professional development as the method to increase sustainable water management within AFNR curriculum. Moreover, the current study contributes to the professional development literature in AFNR education as it is the first known study exploring professional development engagement and inclusion of sustainable water management in AFNR curriculum.

Theoretical Framework

In part, the current study sought to evaluate if, and how, a professional development experience created change among AFNR educators. Specifically, the change sought was an increase in the use of sustainable water management tools within AFNR. Recognizing an interest in teacher change, a framework which modeled the association between professional development and teacher change was needed. In search for such a framework, the *Model of Teacher Change* (MTC; Guskey, 2002) emerged. The MTC is grounded in teacher motivations for engaging in professional development, noting teachers are motivated for three reasons, (a) to expand knowledge and skills, (b) to grow professionally, and (c) to improve student learning (Guskey, 2002). However, the MTC also notes teacher attitudes and beliefs about their teaching practices are not based on their own learning (e.g., via professional development), but the learning and performance of their students (Harootunian & Yargar, 1980). In combination, this foundation of knowledge challenged previous models linking professional development and change, which defined the objective of professional development to directly change the attitudes and beliefs of teachers, which in turn would change their practice (Guskey, 2002). As an alternative conceptualization, the MTC noted teacher change is an experientially-based learning process; specifically, teacher attitudes alone do not influence sustained change, their observations of the efficacy of an intervention creates sustained change. Therefore, the MTC suggested professional development provide teachers with a new practice to attempt within their classroom and, based on student learning outcomes, teachers establish their beliefs and attitudes about the intervention (see Figure 1). Those experientially-grounded attitudes, if positive, provide the foundation for sustained change within a teacher's practice. Below, the MTC is juxtaposed against previous models of professional development.

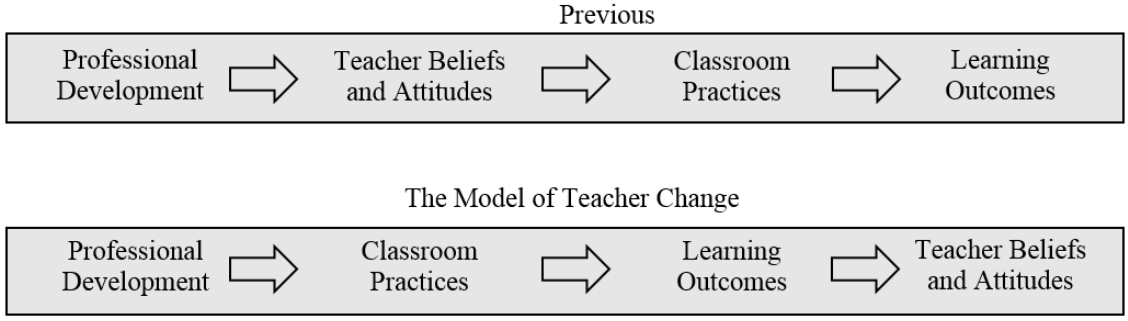

Figure 1. The MTC (Guskey, 2002) in comparison to previous models linking professional development and teacher change.

Within the current study, the MTC was operationalized by having participants engage in a professional development experience and then evaluating anticipated changes in classroom practices (i.e., how teachers envisioned incorporating the sustainable water management tools within their curriculum). A limitation of this approach is neither learning outcomes nor teacher

beliefs and attitudes were evaluated within the current study; however, follow-up research is planned which will attend to the remaining components of the MTC.

Purpose and Objectives

The purpose of this study was to explore how a subset of AFNR educators in the Great Lakes Basin envisioned application of sustainable water management tools within their curricula after engaging in a professional development experience. Two research objectives were established to guide the development and execution of the study, (a) describe AFNR educators' application of the sustainable water management tools within their curricula before and after engagement in a professional development experience and (b) evaluate perceived alignment between the sustainable water management tools and AFNR pathways.

Methods

The current study utilized a convergent design, mixed-method, descriptive approach (Leedy & Ormrod, 2013) to accomplish the established purpose and objectives. The research approach was designed to provide foundational information regarding the inclusion of sustainable water management within AFNR education curriculum. All research methods described were approved by the Institutional Review Board at Michigan State University.

Sample and Data Collection

The current study included a census of teachers (N = 13) who participated in a one-day professional development experience on December 15, 2016. In accordance with the Dillman (2007) tailored design approach, each of the 13 potential respondents were contacted and asked to complete the survey. The survey was administered through Qualtrics, an online survey tool. A maximum of three points of contact were made, facilitated through both email (i.e., first and second contact) and phone calls (i.e., third contact) in February of 2017. In total, 12 of the potential respondents provided useable responses to the online survey, yielding a 92.30% response rate. Due to the small sample size, a statistical comparison of "on-time" and "late" respondents, to evaluate non-response error, was not appropriate (Lindner, Murphy, & Briers, 2001); therefore, the results should not be generalized beyond the 12 teachers who responded to the survey (Miller & Smith, 1983).

Professional Development Experience

The professional development experience, facilitated by three representatives of the Institute of Water Research at Michigan State University, was held at the Shiawassee Regional Educational Service District in Michigan. AFNR teachers from the surrounding area (i.e., within approximately 30 miles) were invited to participate in the training. The sustainable water management training was one element of a longer professional development experience. The sustainable water management training included introductions to, and opportunities to "try out," two online sustainable water management tools. First, participants were provided an introduction to the Michigan *Sensitive Areas Identification System* (SAIS). SAIS is an online mapping and reporting tool that identifies and maps sensitive areas on farm fields. SAIS helps evaluate the conservation needs of a given agricultural field (e.g., viewing areas where concentrated water runoff is likely to occur and cause erosion and loss of nutrients). This information is summarized in a PDF report, mapping potential resource issues on a field and describing conservation practices that could reduce issues. After an introduction to SAIS, participants were given an opportunity for active learning, as they utilized SAIS to map land labs or similar locations close to their respective

schools. Following the active learning opportunity, participants collaboratively discussed how SAIS could be applied within AFNR curricula.

The second sustainable water management tool introduced was the *Great Lakes Watershed Management System* (GLWMS). GLWMS is ideal for evaluating, tracking, and reporting water quality and quantity improvements at the field scale. The system allows users to evaluate impacts on groundwater replenishment and sediment and nutrient loading based on changes in land cover or management practices. Users are also able to save and track results, aggregate benefits across multiple projects, and generate customized reports. Following the introduction, participants were given an opportunity to actively learn GLWMS by evaluating an area relevant to their local school. Additionally, teachers participated in a collective discussion of how the GLWMS could be incorporated within AFNR curricula.

Instrumentation

The follow-up survey included three sections, (a) past and future utilization of the sustainable water management tools in curricula, (b) alignment of the sustainable water management tools and AFNR pathways, and (c) demographic information. Within the first section, respondents indicated their utilization of the sustainable water management tools within their curricula before the professional development, between the professional development and the time of their response, and future plans to incorporate the sustainable water management tools. Responses were collected as "number of days in a typical school year" teachers had utilized, or planned to utilize, the sustainable water management tools. In addition to frequency, teachers were asked, qualitatively, *how* the tools had been, or would be, implemented within their curricula.

The second section of the survey had respondents indicate, on a scale from 0 "absolutely no connection" to 100 "perfect alignment" the alignment between the sustainable water management tools and AFNR pathways and experiences. In total, eleven pathways/experiences were considered in their alignment with sustainable water management tools: the eight AFNR career pathways, sustainable agriculture, FFA, and Supervised Agricultural Experiences (SAE). The final section of the survey included four demographic questions (i.e., sex, years of experience, education, and number of students taught daily).

Data Analysis

Quantitative data, collected via Qualtrics, were downloaded into the Statistical Package for the Social Sciences (SPSS) for analysis. Quantitative data included number of days in a typical school year teachers had previously, or anticipated, incorporating the sustainable water management tools within their curricula (i.e., research objective one) as well as perceived alignment between the sustainable water management tools and AFNR pathways/experiences (i.e., research objective two). The quantitative data were analyzed using means, ranges, and standard deviations. As no attempt was made to generalize the findings beyond respondents, inferential statistics were not used.

Qualitative data were downloaded into Microsoft Word. Qualitative data included respondent descriptions of *how* they had previously, or planned to, incorporate the sustainable water management tools within their curricula (i.e., research objective one). Due to the limited amount of qualitative data collected, a comprehensive coding process was not completed. Instead, full quotes from respondents are provided and discussed. At times, duplicative quotes are omitted to reduce redundant information.

Description of Respondents

Respondents included eight female (66.67%) and four male (33.33%) AFNR educators. On average, teachers had taught AFNR for 11.33 years; however, experience ranged from first year teachers to a teacher with 42 years of experience. One teacher (8.33%) held a Bachelor's Degree with no additional schooling. Five of the twelve teachers (41.67%) had completed "some graduate work" but had not finished a Master's Degree or Ph.D. Similarly, five teachers (41.67%) had completed their Master's Degree. One of the twelve teachers (8.33%) possessed a Ph.D. at the time of data collection. Eleven of the twelve (91.67%) respondents held a dual certification in AFNR and science. One question was asked about the program in which respondents taught, with results indicating teachers taught, on average, 121.70 students within their program on a daily basis. The number of students taught ranged from 70 to 160.

Findings

The first objective sought to describe current AFNR educators' application of the sustainable water management tools within their curricula before and after engagement in the professional development experience. Respondents reported not using the sustainable water management resources (i.e., SAIS and GLWMS) prior to engaging in the professional development experience. Qualitative responses indicated teachers had no familiarity with the tools prior to the professional development experience, as teachers reported they *"had not seen the resources until that meeting"* and *"we did not use it before the meeting."*

As data were collected two months after the professional development session, respondents were also asked if/how they had incorporated the tools since the professional development session. On average, respondents indicated utilizing the sustainable water management tools 0.50 days per school year (SD = 1.45; Range = 0.00 to 5.00; 10 out of the 12 respondents indicated *not* using the tools) since the professional development experience. Qualitative data illuminated the timing did not align with when teachers planned on incorporating the sustainable water management tools; for example, *"I had already taught both my water and soils units"* and *"I am just getting to this in the environmental science unit."* While use of these tools was limited, due to time of the year, one teacher reported, *"I did share the information about [the] resources to the Michigan Horticulture Teachers Association in January,"* indicating the potential utility of the resources beyond the 12 respondents to this study.

With regard to future application of the sustainable water management tools, respondents indicated plans to teach using the tools an average of 3.50 days per school year (SD = 1.94; Range = 0.00 to 7.50). Qualitative responses provide additional insight into *how* teachers planned to incorporate the sustainable water management tools. One educator detailed how it translates to record keeping:

> The resources will be extremely helpful in my Conservation and Natural Resources class. Teaching my students how to use the [Sensitive Areas Identification System] map will help them learn how to evaluate the field we are working in as a class. This software will also help them recognize the importance of record keeping. Because we have to enter details about fertilizer or farm practices used, they will realize that keeping records of the field is important to evaluating the field. (Planned Incorporation = 7.50 days)

Additionally, educators discussed using the tools to "highlight…usage of natural resources and the relationship between agriculture and the environment" (Planned Incorporation = 5.00 days), relate water quality to manure management (Planned Incorporation = 4.00 days), and provide students with "hands-on application of soil conservation" (Planned Incorporation = 5.00 days). However, the feedback provided by teachers was not entirely positive. As illustrated below, one participant perceived the sustainable water management tools as a governmental control mechanism.

> I will explain to all of the students how the government will use this system to monitor farmers, to see if they are in compliance so that they can fine violators, take away farmers' rights, and restrict their ability to purchase needed inputs. The goal is to put small farms out of business so that large farms will be the only ones left and much easier to control. (Planned Incorporation = 2.00 days)

The second objective sought to evaluate perceived alignment between the sustainable water management tools and AFNR pathways (see Table 1). Four of the curricular experiences were rated above 50, indicating stronger alignment between the sustainable water management tools and Environmental Service Systems (M = 73.18; SD = 21.69), Natural Resources Systems (M = 72.82; SD = 22.19), Sustainable Agriculture (M = 69.18; SD = 27.85), and Plant Systems (M = 56.50; SD = 26.28) pathways/courses. Alternatively, only one course had reported alignment below 25, indicating weaker alignment between Power, Structure, and Technology Systems (M = 22.78; SD = 21.81) and the sustainable water management tools.

Table 1

Perceived Alignment between IWR Resources and AFNR Experiences

Pathways/Courses	Minimum	Maximum	Mean	Standard Deviation
Environmental Services Systems	30.00	100.00	73.18	21.69
Natural Resources Systems	30.00	100.00	72.82	22.19
Sustainable Agriculture	15.00	100.00	69.18	27.85
Plant Systems	20.00	100.00	56.50	26.28
Supervised Agricultural Experiences	20.00	70.00	43.50	18.98
Agribusiness Systems	10.00	100.00	36.09	29.42
Biotechnology Systems	4.00	87.00	34.33	30.52
Animal Systems	10.00	100.00	34.27	27.96
FFA	1.00	56.00	31.73	17.55
Food Products and Processing Systems	5.00	61.00	30.70	19.56
Power, Structure, and Technology Systems	5.00	55.00	22.78	21.81

Note. The following descriptions were provided for respondents: 0 "Absolutely no connection between resources and topic/experience" and 100 "Perfect alignment (e.g., the pathway/experience should be taught only using the resources)."

Conclusions and Discussion

"Water is a key resource for the development of any human activity" (Mancosu et al., 2015, p. 987); therefore, water scarcity is a problem we must all contribute to solving. The unmistakable role of agriculture in the over consumption, and eutrophication, of freshwater positions AFNR educators to be change agents by educating the future about sustainable water management. To begin understanding the role of AFNR educators in teaching sustainable water management, the current study explored how a subset of AFNR educators in the Great Lakes Basin envisioned application of sustainable water management tools within their curricula after engaging in a professional development experience.

Before discussing the conclusions of this research, however, important limitations must be illuminated. As mentioned previously, the focus of this research was on the relationship between a professional development experience and anticipated classroom practices; student outcomes, teacher attitudes, and teacher beliefs were *not* explored. Therefore, the current study does not evaluate sustained change among AFNR educators. Additionally, the number of respondents in this study was small (i.e., 12), limiting the scope of understanding to a subset of AFNR educators in the Great Lakes Basin. Acknowledging these limitations, the current study takes a step toward a more comprehensive understanding of how to increase the sustainable water management content and practices taught within AFNR curricula.

The Model of Teacher Change (MTC; Guskey, 2002) suggests sustained change among educators begins with a professional development experience offering educators a new practice to try within their classroom. In total, responding AFNR educators indicated an average planned increase of 3.50 days per school year incorporating the sustainable water management tools within their curricula. These findings indicate, for the majority of respondents, the professional development experience was effective in catalyzing the first step toward sustained change. Qualitative responses support the conclusion of an effective professional development experience. Of particular interest was the variety of ways in which teachers planned to incorporate the sustainable water management tools. From the responses, teachers planned to use the sustainable water management tools to (a) evaluate fields, water usage, water availability; (b) illuminate the relationships between water and soil and water and manure management; and (c) illuminate the importance of record keeping.

Positive perceptions of the sustainable water management tools were not the consensus. It should be noted that for one teacher, no anticipated change in behavior was reported (i.e., did not utilize the sustainable water management tools before the professional development and did not anticipate using the tools after the professional development). Furthermore, one teacher perceived the sustainable water management tools as an opportunity for the government to *"take away farmers' rights, and restrict their ability to purchase needed inputs"* and reported only incorporating sustainable water management tools to *"explain to all of the students how the government will use this system to monitor farmers."* Potentially, the negative perceptions identified in this study relate to the challenges identified in teaching sustainable water management (e.g., political affiliation [Owens & Lamm, 2017] or disagreements between AFNR leaders and general public [Lamm et al., 2015]). Furthermore, the resistance to sustainable water management practices identified among producers due to limited local networking capacity (Fales et al., 2016), may also be the cause for resistance among the minority of AFNR educators in the current study.

In addition to evaluating the relationship between a professional development experience and anticipated incorporation of sustainable water management tools, the current study explored where sustainable water management tools aligned with AFNR courses and experiences. Not

surprisingly, teachers perceived the strongest alignment between the tools and natural resources-focused courses (i.e., Environmental Services Systems, Natural Resources Systems). Three of the bottom courses/experiences, however, illuminate an opportunity to reinforce the application of sustainable water management tools. Specifically, Animal Systems, FFA, and Food Products and Processing Systems provide an opportunity for educators to engage learners in thinking systematically about food production systems, water management, and social dynamics. These learning opportunities can address the often-missed social dynamic of water scarcity and sustainable water management (Breukers et al., 2012).

Recommendations

Recommendations emerging from this research have been concatenated into recommendations for practice and recommendations for research. The first recommendation for practice is for AFNR educators from across the country to leverage their unique position to address water scarcity through the incorporation of sustainable water management strategies. While the current study did not holistically evaluate teachers' incorporation of sustainable water management prior to the professional development experience, evidence emerged suggesting AFNR teachers could be doing more to educate students about water scarcity, sustainable water management, and the critical role of agriculture. For teacher leaders (e.g., teacher educators, professional organization leaders, state education leaders), it is recommended the professional development experience described in this study be utilized as a template for designing and developing a similar experience to illuminate sustainable water management tools available locally, including some of the tools described in this study. Teacher leaders in AFNR education are also encouraged to model professional development experiences after the Model of Teacher Change. Importantly, this model highlights the need for professional development experiences which (a) recognize change among educators is a gradual, not immediate, process; (b) ensure teachers are equipped to measure, and reflect upon, student outcomes associated with a given intervention; and (c) provide continued support for educators engaged in professional development sessions (Guskey, 2002).

From a research standpoint, the current study provides a foundation for continued thinking about the incorporation of sustainable water management within AFNR education. To build upon the work done, future research will follow-up with the participants in this study to evaluate student outcomes and resultant teacher attitudes and beliefs, providing a more complete picture of the sustained teacher change process described in the MTC (Guskey, 2002). Furthermore, replicated professional development sessions and evaluations are encouraged with larger audiences of AFNR educators to improve understanding how teachers with different backgrounds, beliefs, and values implement, or resist implementing, sustainable water management within their curricula. While not explored in much depth, the origins of the negative perceptions uncovered by the minority of teachers in the current study is also worth additional research. To guide future studies, an analysis of local networking capacity and perceptions of sustainable water management is recommended.

Globally, social and environmental conditions indicate water scarcity is only going to get worse (Mancosu et al., 2015), intensifying the need for sustainable water management. AFNR education has an opportunity to be a leading force in sustainable water management by engaging future AFNR producers, leaders, and decision makers in education about sustainable water management. Results from the current study offer a promising path forward, using professional development to initiate sustained teacher change. A brighter, more sustainable world may rest on our ability, as a discipline, to contribute to a solution to water scarcity.

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