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Knowledge Co-Production with Agricultural Trade Associations

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Received: 31 July 2020; Accepted: 17 November 2020; Published: 18 November 2020

Abstract: Scientists and agricultural trade associations may further conservation outcomes by engaging with one another to uncover opportunities and engage in social learning via knowledge co-production. We observed, documented, and critically reviewed knowledge exchanges among scientists and agricultural stakeholders working on a multidecadal water conflict in Wisconsin. Differences in knowledge exchange and production were related to meeting spaces, organization, time management, and formality of interactions. We found that repetitive, semiformal meetings organized and led by growers facilitated knowledge exchange, co-production, and social learning. However, scientists often appeared uncomfortable in grower-controlled spaces. We suggest that this discomfort results from the widespread adoption of the deficit model of scientific literacy and objectivity as default paradigms, despite decades of research suggesting that scientists cannot view themselves as objective disseminators of knowledge. For example, we found that both scientists and growers produced knowledge for political advocacy but observed less transparency from scientists, who often claimed objectivity in politicized settings. We offer practical methods and recommendations for designing social learning processes as well as highlight the need to better prepare environmental and extension scientists for engaging in agribusiness spaces.

Keywords: extension; farmer; social learning; knowledge co-production; science communication; science literacy; knowledge exchange

1. Introduction

In the US, 80% of freshwater in lakes, streams, wetlands, and aquifers comes from precipitation [1]. Additionally, 51% of US land area or 469 million hectares is in agricultural land use, which includes both cropland and grazing land [2]. By interacting with and partitioning precipitation and irrigation into runoff, recharge, discharge, and evapotranspiration, agricultural land use can degrade surrounding and embedded freshwater ecosystems by diverting and polluting ground and surface waters. The freshwater degradation associated with agriculture is often watershed specific; it depends on the connectivity of surface and groundwater, other prevalent land uses, soil properties, crop types, and agronomic management practices [3]. Without management, there are inherent tradeoffs between agricultural production and freshwater health. For example, when groundwater is extracted to meet crop water needs, adjacent streams and lakes may become depleted [4]. Agricultural stakeholders are in many cases resistant to water conservation efforts that may increase the regulation of water quantity and quality [5]. Partnerships between agricultural stakeholders and scientists are challenging but may be uniquely poised to address freshwater degradation at the watershed scale. As scientists who regularly partner with agricultural stakeholders, we are motivated to better understand how scientists can alleviate or exacerbate community water conflicts through knowledge production and exchange via social learning.

Partnerships between scientists and agricultural stakeholders can uncover motives, mobilize concepts between social groups [6,7], facilitate social learning [8], and create spaces where realistic environmental solutions can be negotiated [9–12]. However, it is important for scientists to avoid common pitfalls associated with stakeholder engagement, such as stealth advocacy [13] and excessive objectivity [14]. Advocacy is defined as using knowledge (scientific or other) to increase or reduce the number of available environmental actions or judge the ethics and efficacy of these actions [15]. Stealth advocacy occurs when scientists do not acknowledge how their personal values are embedded in their own research questions, design, execution, interpretation, and presentation of associated environmental actions [13,16]. Avoiding stealth advocacy is especially important when engaging with stakeholder groups, because scientific knowledge is often used as evidence in environmental advocacy [17]. In conflicts, different stakeholders, including scientists, may inadvertently or intentionally use knowledge or highlight missing knowledge to support advocacy [17]. In this work, we examine the knowledge production and exchange that occurs among different types of scientists and growers in the midst of a decadal community conflict over agriculture and freshwater quantity. Aligning with the special issue, we consider the development of social learning in complex or "wicked" regional water conflicts that cannot be solved using science and engineering [18]. Our study also contributes to the practice-informed literature and offers insights into the methodology and design of social learning processes for scientists partnering with agricultural trade associations embedded in community water conflicts.

There are many approaches for partnering with growers to manage water resources, characterized by the development of long-term relationships, mutual trust, respect, and equity in the process of knowledge exchange [19,20]. The process of knowledge exchange includes the spaces and actions through which information is developed, translated, shared, and used among different groups; one of which is often scientists [21]. Knowledge co-production occurs when stakeholders (including scientists) merge knowledges, ideas, language, experiences, and values to develop new knowledge forms and practices [22]. Social learning and knowledge co-production are related, but distinct ideas. Social learning can be considered as the processes through which knowledge is co-produced [18] and new knowledge co-production is a key outcome of social learning processes [23]. The dynamics of social learning, knowledge production, and exchange between scientists and growers have been explored in great detail in cases where the educational, institutional, and communicative power of scientists greatly outweighs the power of growers [24–28]. This body of literature focuses on the need to hybridize local and scientific knowledge in order to avoid scientific imperialism or a one-way transfer of information, which is especially important when there is significant power asymmetry between scientists and farmers [29]. Less attention has been given to knowledge production and exchange where the power differential between scientists and growers is equal or skewed towards the growers. In these cases, growers organize as agricultural trade associations (e.g., commodity boards) that collect, produce, and distribute knowledge to drive policy, secure resource access, influence regulations, and critique the causality of environmental problems [30,31].

Agricultural trade associations participate in scientific knowledge production by directly soliciting and funding research proposals on topics and initiatives that are important to commodity markets and entrepreneurship (e.g., productivist goals) [32]. When scientists and growers share productivist goals and have a strong institutional infrastructure, they are also able to co-innovate by developing and exchanging knowledge together [32,33]. In extreme cases, these partnerships can form a type of research-industrial complex to advance productivist goals by excluding contradictory knowledges or perspectives [31,34]. Here, we examine social learning, knowledge production, and exchange among scientists and growers with varying degrees of productivist and/or water conservation goals and motives. We conceptualize knowledge production in relation to social learning processes by examining the spaces, interactions (e.g., transfer vs. deliberation), and meeting features that facilitate knowledge co-production.

We focus our inquiry on grower–scientist interactions in the midst of a seventy-year community conflict over freshwater resources in the Central Sands region of Wisconsin. The most recent mediation efforts facilitated by academics at the University of Wisconsin took place between 2010 and 2012 including growers, conservation organizations, policy makers, and scientists in attempts to reach a bottom-up consensus. These attempts failed as the scientists involved were observed to either advocate for one position or claim objectivity advocating for more research without specifying how the research would contribute to outcomes (P. Nowak, personal communication, 2014). We examined knowledge exchange and communication between growers and scientists in the wake of this failed consensus building attempt to better understand some of its causes and legacy effects. Our research goals were to: (1) observe and document different types of knowledge production and exchange in scientist and grower interactions; (2) understand how different settings enhance or deter knowledge co-production and nurture productive conflict; and (3) identify strategies and pitfalls for scientists attempting to partner with agricultural organizations that have financial and political power.

2. Approach

2.1. Land Use and Conflict History

The Central Sands was named for the coarse glacial aquifer that supports 1000 km of headwater trout streams, >80 lakes, and numerous wetlands [35]. The sandy soils in the region hold limited water and nutrients, making rainfed agriculture a risky venture despite the humid climate. During the Wisconsin Dust Bowl of 1933–1935, farms in the Central Sands lost ~1 million tons of topsoil to wind erosion [36]. An abundant supply of aluminum pipe remained following World War II and growers began using it to extract groundwater from high-capacity wells [37]. Land-use conversion to groundwater irrigation increased potato yields from 100 to 450 bushels per acre and revolutionized agriculture in the Central Sands along with fertilizer, pesticide, and breeding advancements [38]. In the 1950s, growers with sufficient means invested heavily in center-pivot irrigation and bought out their neighbors. As the number of farmers decreased and production intensified, the number of high-capacity wells grew from 50 in 1960 to over 2700 in 2016 [39]. Today, irrigation in the Central Sands contributes to making Wisconsin one of the top five producers of potatoes, sweet corn, snap beans, and peas in the United States [40,41]. Production is concentrated to 100–150 farms, which wholly participate in an agricultural trade association known as the Wisconsin Potato and Vegetable Grower Association (WPVGA).

The WPVGA was formed in 1948 and its mission is to educate growers, engage in political advocacy, fund and engage in scientific research, and promote industry. Grower participation in the association is almost absolute and attendance at events is abundant. The permanent staff of the WPVGA includes an executive director, magazine editor, communications director, financial officer, auxiliary president, community relations coordinator, and administrative assistants. For political advocacy, the group retains a lobbying firm that specializes in environmental law and government relations. The WPVGA has engaged in political action to protect and expand pumping rights over the past sixty years [42,43], which have been highly contested [38]. Seminal studies predicted severe water quantity impacts to lakes, rivers, and wetlands adjacent to high-capacity wells [44,45]. These predictions came to fruition during 2005–2009 when unprecedented surface water stresses and fish kills occurred near areas of intense groundwater pumping in the Central Sands in the absence of drought [35,46]. The Little Plover River, an iconic class I trout stream, ran dry and suffered unprecedented fish kills, which caused an outcry amongst recreational water users and freshwater conservationists [47].

Groundwater and surface water are inextricably linked by Central Sands hydrogeology [4] and irrigated agriculture has been tied to seasonal reductions in groundwater recharge and changes in the regional climate [48,49]. However, they are presently governed as separate resources in Wisconsin. Growers receive irrigation permits as long as wells are located 365 m from an outstanding or exceptional water resource (Wis. Stat. §281.15) and can transfer, replace, or reconstruct wells without new permits (Wis. Stat. § 281.34). As we previously mentioned, in 2005–2009, unprecedented surface water stresses and fish kills occurred near areas of intense groundwater pumping [35]. Lakefront homeowners and recreational water users organized against existing and continued irrigated agricultural development fearing a further loss of fisheries and wildlife habitat, property values, and tax base. There has been ongoing litigation as to the authoritative extent of the Wisconsin Department of Natural Resources (WDNR) over state waters held in public trust since 2011 (335 Wis. 2d 47; Appeal 2018AP59, 2019).

In response to the 2005–2009 water stresses and controversy, the WPVGA created a task force of about twenty growers who are also community leaders, adjacent industry representatives (e.g., well drillers, processers), municipal administrators, and scientists to "be an advocate for responsible water use practices and informed, science-based public policy that will protect the Central Sands groundwater aquifer and its associated streams, lakes and wetlands; promote and maintain a sustainable agricultural industry; and foster vibrant rural communities" [50]. The taskforce meets bimonthly and invites stakeholders to give presentations about Central Sands water issues and research. Scientists in the Central Sands research community are housed in the University of Wisconsin, the United States Geological Survey, the Wisconsin Geological and Natural History Survey, the Wisconsin Department of Natural Resources, and private consultants retained by individual growers or the taskforce. Most scientists live 100 miles south of the Central Sands in Madison, WI. Moreover, in recent years, larger Central Sands agribusinesses have hired University of Wisconsin faculty and graduates as industry scientists to conduct on-farm research and advise policy on various aspects of water and nutrient management.

2.2. Methodological Approach

We collected participant observation data and analyzed the WPVGA's website, public relations commercials, and High Capacity Well Fact Book to inform this study. Participant observation data were collected using standard techniques detailed below [51] for one year (24 June 2015–23 June 2016) within or regarding the Central Sands region of Wisconsin. During the participant observation period, we attended eight WPVGA task force meetings, the cosponsored WPVGA/University of Wisconsin Extension Grower Education Conference, the Extension potato field day at a University of Wisconsin Agricultural Experimental Station, the American Water Resources Association Wisconsin Section Meeting, as well as several informal scientific meetings. As members of the University of Wisconsin scientific community, our presence at these events was invited and expected. We categorized participant observation data into three types of knowledge exchanges: scientist–scientist, grower–scientist, and grower–grower interactions. These exchanges occur in four different types of spaces: scientist-only, traditional extension (scientist-led), task force (grower-led), and grower-only spaces. We collected participant observation data from all types of exchanges in scientist-only, scientist-led, and grower-led spaces and use these data to support our findings. We also analyzed knowledge and content publicized by the WPVGA via the organizational website—specifically focusing on public relations videos that aired as commercials and the High Capacity Fact Book. We considered these videos and the fact book as WPVGA knowledge products. WPVGA knowledge products, observed grower–grower knowledge exchanges in grower–scientist spaces, and literature were used to inform findings related to grower-only spaces. This study was proposed, reviewed, and approved by the Institutional Review Board (IRB) for Education and Social/Behavioral Science at the University of Wisconsin-Madison (IRB identification number: 2015-0338). There were no significant IRB issues or amendments required.

In order to differentiate our participant-observation from our normal participation as scientists in the community, we applied six recommended data collection techniques [51]: (1) we were actively aware of our dual roles as both scientists and observers during data collection events; (2) we maintained a sense of hyper-awareness of our surroundings and processed information that we would normally ignore to avoid information overload; (3) we used a "wide-angle lens" to observe people, spaces, and interactions; (4) we attempted to engage with both scientists and farmers as an insider, while observing both ourselves and the surroundings as an outsider; (5) we employed a higher than normal degree of introspection about our behavior and observations; and (6) we kept records of data collection in the form of narrative memorandums with any notes or quotations transcribed within one day of interactions/observations. Our conversations that occurred during the participant-observation period are considered analogous to interviews with the lowest possible amount of control (less control than unstructured interviews) because we still used active-listening techniques, nonintrusive verbal cues, and clarifying or naïve questions to elicit information from both farmers and scientists [52].

We used a qualitative analysis approach for participant observation data that involved the inductive coding, indexing, linking, selective sampling, verification, and triangulation of themes and linkages [52,53]. We used inductive coding to identify themes in the memorandum data and indexing to organize the data based on a priori interests into different types of knowledge (scientific, local, co-produced), knowledge transfer and exchange, and knowledge spaces (casual, semiformal, formal) [51,52]. We iteratively compared coded memorandums to locate links and connections that formed main ideas or themes [54]. After identifying themes, we selectively sampled coded memorandums for additional supporting data [52,54]. Finally, we ground truthed and triangulated linkages and themes from the participant observation data with WPVGA knowledge products (e.g., public relations commercials, reports, fact books) [55].

The quality of participant observation data is influenced by the degree of participation, biases, and cultural identity of the researchers as well as the stakeholder acceptance of participant observation activities [52]. The participant observation data were primarily collected by an author who identifies as an interdisciplinary conservation scientist and a woman of color in spaces dominated by white men (this includes both grower and hydrological spaces). Our degree of participation in both the WPVGA groundwater task force and scientific community is complete. We entered the research community following the failed mediation attempts. Although we did not participate in these mediation efforts, we acknowledge that there may have been legacy effects leading to an environment distrusting of scientists—especially hydrological scientists. We built working relationships and trust with growers in the WPVGA community prior to the participation observation period. We regularly attended WPVGA groundwater taskforce meetings, University of Wisconsin Madison Extension events (Grower Education Conference and Potato Field Day), American Water Resources Association Section Meetings, and informal scientific meetings for three years prior to commencing the study, and continued to attend meetings following the study period. Additionally, we studied biophysical and agrohydrological processes in the Central Sands region for three years prior to the study period and continue these studies to date [48,49,56,57]. We identify as conservation scientists in that it is our goal to do policy-relevant research that supports the management and sustainable use of water resources in Wisconsin.

3. Results

3.1. Knowledge Exchange and Production

All types of meetings facilitated the exchange of scientific and local knowledge, however, the directionality of knowledge exchange and production differed based on observed leadership (scientist vs. grower) and arrangement of spaces. We visualize social learning processes, knowledge exchanges, and key findings in Figure 1. Scientists gave didactic presentations at the Grower Education Conference and Potato Field Day following the deficit model of science literacy where knowledge is produced by scientists and transferred to growers in a one-way exchange. The scientists used nearly all of their 20–30-min allocations and growers rarely asked more than 1–2 questions following didactic presentations ((2) in Figure 1). We observed knowledge exchanges during informal spaces and moments at the Grower Education Conference and Potato Field Day (e.g., coffee breaks, meals), but no new knowledge was co-produced. Additionally, we did not observe key social learning processes needed for co-production at these events. For example, we did not observe any deliberation, persuasive exchanges of knowledge, or iterative interactions.

We observed social learning via deliberation, spirited knowledge exchanges (conflicts and agreements), iterative interactions, and over time, knowledge co-production at task force meetings, which differed in organization and format from Extension meetings. Though scientists used slides, presentations were more dialogic at task force meetings. The grower-led space altered presentation structure, timing, and formality. Speaker timing allocations were not enforced, which facilitated discussion and deliberation ((3) in Figure 1). Task force members debated with speakers and amongst themselves. These debates ranged from friendly, evidenced by smiles and banter, to impassioned, evidenced by elevated voices and tears. One scientist said they regularly felt bullied by the group. We observed several of the same scientists give talks to this group and to the closed scientific community. Scientists were more uncomfortable in grower-led spaces with the exception of extension practitioners. Experienced extension practitioners code-switched by adapting different vernaculars when growers were present, especially in grower-led spaces ((5) in Figure 1).

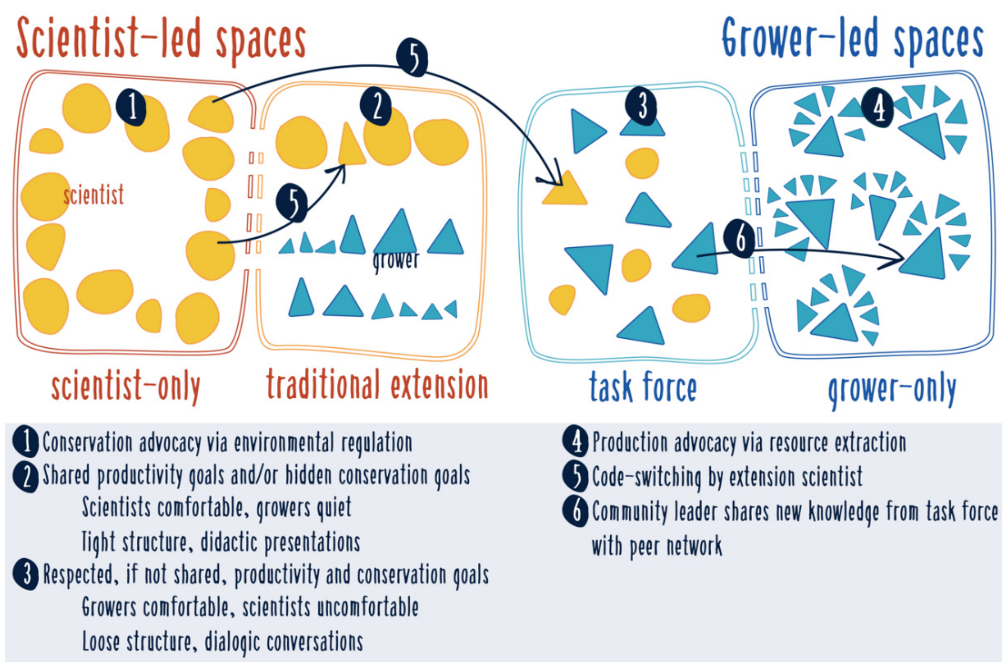

Figure 1. Conceptual visualization of spaces, knowledge exchanges, and production between scientists and growers (original artwork). Scientists are generally represented as orange rounds and growers are represented as blue triangles. Larger shapes indicate community leadership (e.g., all grower task force members are community leaders). Scientists changing from orange rounds to orange triangles indicate code-switching in traditional extension or task force environments.

There were differences in behaviors and power-based interactions between industry, consulting, and conservation scientists in grower-led spaces. For example, one industry scientist was protective and secretive about the policy and strategizing portion of task force meetings. This scientist kindly asked all non-industry scientists (including participant observers) to leave meetings when growers started strategizing about policy, stating that the "science portion of the meeting was over." However, in meetings that occurred in the physical absence of that particular industry scientist (all other task force meetings we attended during the study period), all scientists (including participant observers) were included in all portions of the meetings.

3.2. Knowledge Used for Advocacy

Both growers and scientists produced, highlighted, and discounted knowledge for advocacy. Growers were transparent about advocacy as it is in the WPVGA's mission. Advocacy products were concerted, funded efforts. For example, the task force produced a public relations commercial to emphasize that trees use more water than irrigated crops [58]. Additionally, the task force produced and distributed a product called the "High Capacity Well Fact Book" to county and statewide policy makers that contained a mixture of scientific knowledge, narratives, economic impacts, and demonstrative figures that collectively challenge the causal link between irrigated agriculture and freshwater degradation [59]. In the High Capacity Well Fact Book, hydrological jargon is juxtaposed with straightforward calculations and common-sense experiences. For example, we observed a grower presenting precipitation and groundwater withdrawal graphs from the book. These graphs were accompanied by rhetoric such as "Now, I'm no scientist, but it looks like there is much more water going in than out." The book also contains portions of peer-reviewed studies that support the assertions that forests, rather than high capacity wells, may be driving surface water declines.

Scientists were less transparent about using knowledge for advocacy. They often declared their objectivity and impartiality in mixed spaces with growers. However, the scientists spent considerable time in closed spaces ((1) in Figure 1) advocating for regulatory policy solutions and discussing what to do about the "tree problem". Some scientists dismissed the credibility of the High Capacity Well Fact Book by publicizing methodological limitations underlying any findings that trees could use more water than irrigated crops on an annual basis.

Scientists produced and distributed knowledge products including agrohydrological models, which were a source of conflict among growers and scientists. We observed that scientists introduced these models as decision-support tools capable of depicting different ecosystem services or disservices, stakeholder-driven outcomes, and stated their major assumptions and limitations. As one senior grower stated during lunch at a WPVGA task force meeting, "They *say* all the right things." However, during an unstructured break at the Grower Education Conference ((2) in Figure 1), the same grower warned that models were going to be used to "tell us how many gallons we can pump" and that "the water budgets are coming." This concern was legitimate, as scientists advocated by choosing which simulations to present to the community. For example, an early-career scientist presented a model simulation at a task force meeting that brought back streamflow in response to removing several irrigation wells. Growers asked whether "any other solutions worked" and "why they didn't do the simulations that we asked for." Though the scientist acknowledged that the simulation results were "emotional and challenging to look at", some growers became very upset that these simulations had been conducted. One grower stated that removing the wells was "not an option" and another grower stated that the group does not want "just models" anymore and they want "real data". The presenting scientist became visibly distressed responding to these critiques, emphasized the expertise of senior scientists, and exclaimed that they were just trying to help the community. In a separate task force meeting in reference to our own prospective modeling research, an early-career grower brought up frustration that model results are based on decisions or "knobs" that only scientists manipulate. They suggested, "It seems like when you guys turn the knobs one way, you get a particular set of results. We want to see what happens when you turn the knobs the other way." These examples are representative of many of the conversations that occurred during task force meetings, where growers appeared most comfortable and scientists appeared most uncomfortable ((3) in Figure 1).

4. Discussion

4.1. Repetitive, Semiformal Meetings Facilitate Knowledge Co-Production

Scientists and growers co-produced knowledge at the task force meetings through social learning processes that included frequent deliberation, iteration, and developing a common language [60,61]. For example, we codeveloped knowledge over several groundwater task force meetings using a bank account analogy to describe inputs and outputs to the aquifer as a water budget. We saw evidence that social learning had taken place and extended into the larger community when we heard growers casually discussing water budgets in this banking context during unstructured breaks at extension events. Co-produced knowledge provides a foundation for social consensus, making it more important than scientific knowledge when seeking to identify community-based water management opportunities [62]. Additionally, co-produced knowledge is not a complete representation of scientific facts, theories, and mechanisms; it facilitates communication across social structures. Though the bank account analogy was not a perfect representation of hydrological water budgets, it greatly facilitated discussion about our finding that net groundwater recharge could be negative or positive in a given timeframe [49]. We suggest that knowledge co-production requires repetitive, iterative interactions and participation between farmers and scientists with increasing depth or "progressive engagement" [10]. The semiformal nature of the meetings and use of slides were important for anchoring and revisiting discussions. The use of slides coupled with the lack of agenda enforcement and freedom for audience interruptions provided a space that was balanced between participation and presentation [63].

4.2. Legacy of the Deficit Model in Extension Traditions

We observed that many of the traditional extension activities, including field days and grower education conferences are based on the deficit model of science communication [27], where growers receive knowledge from scientists who are assumed to be objective and unbiased. For example, grower education conferences were organized to have scientists present using a microphone and electronic slides in front of growers organized into an audience. Growers were not able to interrupt with questions until presentations were finished and approximately five minutes were allocated for questions. However, scientists almost always went over their time limits leaving 1–2 min for very brief questions from growers. Field days involved growers sitting in bleachers pulled by a tractor to different study plots at the agricultural experimental station. At each plot, scientists presented information about the study they were conducting, and growers once again were able to ask questions following presentations (no interruptions). These traditional activities may be classified as successful engagement by scientists who are motivated by agricultural production outcomes and as a result, appear unbiased to growers (Figure 2A). However, scientists motivated by conservation are more likely to define successful engagement by outcomes (e.g., changes in practices and policies) than activities [10]. These scientists will be frustrated trying to change outcomes using the deficit model of science communication with stakeholders who have different goals, especially when conservation goals and biases are not acknowledged (Figure 2B). Here, we find that the meeting purpose, spaces, and organization can alter the dynamics of knowledge exchange towards co-production, which is more desirable for outcomes-based engagement during environmental conflicts (Figure 2C). Though the power dynamics are often different, our co-production findings share some similarities with the co-innovation literature [64–67]. Traditional extension activities that follow the deficit model of science communication (e.g., didactic, agenda-enforced meetings) may not be the best choice for facilitating either knowledge co-production or co-innovation of agricultural technologies [32]. In both cases, it is beneficial to consider unconventional forums and spaces where scientists, growers, and other actors can meet repeatedly, frame different motives and biases, develop a common language, and collectively assess environmental impacts and responses [32,66].

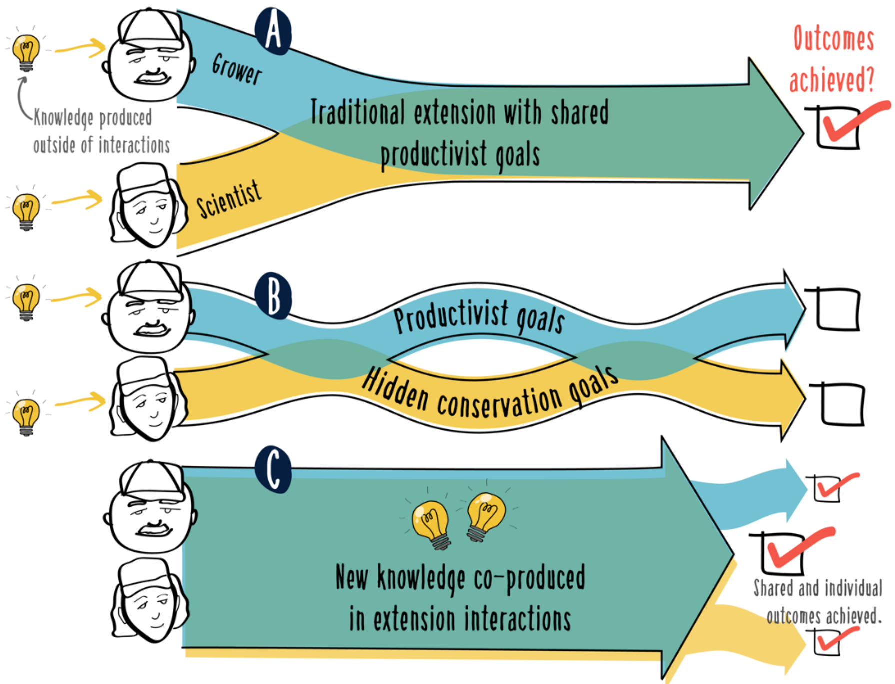

Figure 2. Knowledge exchange and production scenarios for growers and scientists (original artwork). Light bulbs indicate new knowledge production related to goals. Scenario (**A**) illustrates knowledge exchange when growers and scientists share productivist goals. Scenario (**B**) illustrates knowledge exchange when scientists have hidden conservation goals. Scenario (**C**) illustrates knowledge co-production when growers and scientists have differing goals, but engage in repeated interactions brokered by trade associations.

We did not observe any purely equitable spaces between scientists and growers. However, the lack of formality and progressive engagement that occurred during groundwater task force meetings facilitated deeper knowledge exchange and production. For example, growers regularly engaged in storytelling about droughts and floods, which can be a valuable form of knowledge expression and exchange that takes place when formality is low [68]. In our opinion, the comfort of growers outweighed the discomfort and stress of scientists during groundwater task force meetings for the goal of conducting policy-relevant science. However, it is important to note that in this case study, the agricultural trade association effectively took on a brokerage role. The history of the failed academic-led knowledge exchange processes and effectiveness of grower-led processes suggests that the leadership and brokerage role of the agricultural trade association may be an important influence on the dynamics of the interactions. When scientists claim objectivity (e.g., no interests or biases) in environmental conflicts as in this case, it indicates that they do not have the training or worldview to broker science-based policy choices [16,69]. When scientists claim objectivity, it can also indicate that conditions are optimal for stealth advocacy [69]. Under these circumstances, we posit that agricultural trade associations may be better brokers. However, there are risks associated with shifting social learning efforts into grower-led spaces, such as scientist distress or discomfort as well as the potential for research-industrial complexes to form. To help mitigate these risks, we strongly suggest transdisciplinary collaboration as well as mentorship and training for scientists (see below).

4.3. Modeling Studies Need Transdisciplinary Collaboration

Despite grower mistrust, hydrological models are considered amongst scientists to be the best tools for planning, forecasting, evaluating solutions, and assessing water resource and conservation needs at the regional, national, and global scales [70,71]. One possible option—the modeler's solution—is to incorporate stakeholder behavior into ecosystem models to create hybrid socio-environmental models that optimize stakeholder outcomes [72]. However, many water conflicts fall into the category of "wicked problems," [73] to which there are, by definition, no optimal solutions, rather only "clumsy" [74], exploratory solutions that are devised with inputs from stakeholders, though all stakeholders will not agree to clumsy solutions for the same reasons [74]. Alternatively, we recommend that conservation scientists start all regional-scale modeling projects by acknowledging their advocacy/stakeholder role and biases, which is the opposite behavior to what we observed. To the scientists who presume that they hold no biases in environmental conflicts, we assure them that they do and ignoring these biases will lead to stealth advocacy [13,69]. It is also likely that physical scientists that claim objectivity and regularly use didactic communication (i.e., the deficit model) are not collaborating with social scientists [75]. Thus, we strongly recommend including social scientists and science communication experts on modeling teams during all stages of project development and execution to help establish biases, expectations, and share modeled output as *conditional* outcomes [76].

4.4. Training for Scientists Engaging with Agricultural Groups

Scientists doing policy-relevant extension work require different rules of engagement when their political beliefs and advocacy goals do not align with stakeholders. Moreover, the inadvertent code-switching we observed in experienced extension scientists could be classified as a strategic behavior to promote knowledge exchange, common language production between cultural groups, and encourage specific outcomes [77]. Becoming aware of and intentional about code-switching between academic and agricultural worlds could help scientists in agribusiness spaces. Early-career scientists need training to do this type of extension, especially when they are moving between academic and rural communities attempting to act as agents of change. We recommend that mentors work with early-career scientists to conduct identity-based risk assessments prior to mentees entering grower-led spaces where world views and identities could differ enough to cause distress, discomfort, or wellbeing concerns [78]. These assessments could include talking with mentors/colleagues who work in grower-led spaces to identify potential harms/triggers and developing a plan for how early career scientists will react when encountering these potential harms. We recommend that readers consult Demery and Pipkin (2020) for more information about how to conduct identity-based risk assessments [78]. If scientists decide to engage in grower-led spaces, we recommend developing coping strategies known to build professional resilience in uncomfortable or stressful spaces, such as identifying specific personal triggers, having a plan for responding to stressors, mindfulness or meditation exercises, and strong supportive relationships with mentors and peers [79]. Finally, we recommend that scientists learn about alternative approaches (e.g., knowledge co-production) to the deficit model of science communication, which can operate as the default setting for scientists without intervention and training.

5. Recommendations and Conclusions

We conducted a detailed case study examining how different knowledge exchanges facilitated co-production with a single agricultural trade association in the Midwestern United States. We observed social learning processes in meetings brokered by the agricultural trade association. The spatial and temporal characteristics of these meetings facilitated social learning processes—deliberation, persuasion, iterative conversations, storytelling—as well as knowledge co-production related to water. Here, we generalize our findings for a broader population of scientists engaging with growers by offering recommendations related to the methodology and design of social learning processes for scientists partnering with agricultural trade associations embedded in community water conflicts. We note that these recommendations are most appropriate for scenarios where agricultural trade associations have equal or greater socioeconomic power to scientists and practitioners. We also note that recommendations may function as hypotheses to be tested and improved upon outside of this case study. The recommendations are developed in detail throughout the paper, but we summarize them for clarity here:

1. *Training*. Seek out alternatives to the deficit model of science communication (e.g., knowledge co-production), which will otherwise act as the default theory of engagement [75].
2. *Training.* When agricultural stakeholders have very different identities or world views, it is important for scientists to conduct identity-based risk assessments prior to engagement, similar to what is now recommended for biophysical field work [78]. If scientists decide to accept these risks, they should develop coping strategies (e.g., trigger identification, response planning, mindfulness, strong practitioner networks) to deploy during and after engagement [79].
3. *Study design.* Physical, social, and extension scientists should collaborate from project proposal to completion to help establish biases, expectations, and share conditional outcomes [76].
4. *Study design.* Scientists should start all collaborative projects with agricultural stakeholders by critically acknowledging their own positionality, advocacy/stakeholder role, and biases.
5. *Meeting organization.* Choose grower-controlled spaces to hold meetings that facilitate knowledge exchange and co-production. These may be spaces that are either associated with agricultural trade associations or regularly used by agricultural trade associations.
6. *Meeting organization.* Keep an agenda, but relax schedule enforcement and promote questions, interruptions, and dialogue during scientific presentations. Ideally, a member of the agricultural trade association is responsible for agenda enforcement.

We recognize that there are inherent biases to our participant observation based on our degree of engagement, biases, and cultural identities. In this case the primary participant observer engages in code-switching behaviors in grower spaces, thus was uniquely poised to identify and diagnose code-switching (or lack thereof) by other scientists. An additional limitation inherent in this work is the lack of participant-observation in grower-only spaces. Though we feel confident in our classification of task force members as community leaders, we infer the flow of knowledge from community leaders to other growers based on previous findings highlighting peer-to-peer networks and experiential learning as key drivers of knowledge exchange in agricultural communities [80,81]. We also emphasize that knowledge co-production does not create failure-resistant governance efforts and should not be depoliticized [82], especially when engaging with financially and politically powerful agricultural trade associations. Rather, the findings of this study should be used to build effective co-production spaces and meetings, train future scientists, and reevaluate traditional extension practices.

Author Contributions: Conceptualization, M.A.N and N.W.F.; methodology, M.A.N and N.W.F.; formal analysis, M.A.N.; resources, C.J.K.; writing—original draft preparation, M.A.N.; writing—review and editing, M.A.N, M.N.S, N.W.F., C.J.K., B.M.M.; visualization, B.M.M., M.A.N.; supervision, N.W.F., C.J.K.; project administration, M.A.N.; funding acquisition, M.A.N., C.J.K. All authors have read and agreed to the published version of the manuscript.

Funding: The research described in this study has been funded in part by the United States Environmental Protection Agency (EPA) under the Science to Achieve Results (STAR) Graduate Fellowship Program. EPA has not officially endorsed this publication and the views expressed herein may not reflect the views of the EPA. Additionally, this work is a product of research funded by the Wisconsin Department of Natural Resources, University of Wisconsin Consortium for Extension and Research in Agriculture and Natural Resources, the United States Department of Agriculture Sustainable Agriculture Research and Education program, the Smith Family and Wisconsin Potato Industry Board Distinguished Graduate Fellowships, as well as the David H. Smith Conservation Research Fellowship.

Acknowledgments: We acknowledge and thank the Wisconsin Potato and Vegetable Grower Groundwater Task Force and the scientists working in the Central Sands region for collaborating with us. Additionally, we acknowledge Steve Loheide, Eric Kruger, Matthew Ruark, George Kraft, Pete Nowak, and the late Jeff Wyman for assistance with research development and manuscript review.

Conflicts of Interest: We have received research grants and graduate fellowships from the Wisconsin Potato and Vegetable Growers Association. The Wisconsin Potato and Vegetable Growers Association and our other funders had no role in the design of the study; in the collection, analyses or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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