Growing Knowledge: Epistemic Objects in Agricultural Extension Work

Abstract: We outline a specialized form of knowledge arising from established communication practices between farmers, university researchers, and regulators. The *grower standard* is a benchmark concept in agricultural experiments that differs from familiar epistemic objects in philosophy of experiment such as controls or background conditions. It is a unique, institutionally-structured way in which agricultural experiments are value-laden. Grower standard is not a one-size-fits-all standard. It is the product of active interactions between diverse agricultural communities of stakeholders within *agricultural extension* communication practices. Exploring this form of knowledge coproduction, we explore the role extension work plays in shaping agricultural science more broadly.

1. Introduction

In Kentucky, agricultural experiments on tobacco crops need to be planted by June 20. Fungicide experiments on grapevines in Oregon begin when the plants achieve six inches of growth. In Missouri, cotton pest management experiments count the nodes above the highest first position of white flower (NAWF) to determine when to terminate insect control practices. These peculiarities of experimental design each originate from the concept of *grower standard*. Grower standard is a benchmark concept used in agricultural science. It furnishes the basis for comparison between farming practices and agricultural experiments.

Some considerations relevant to grower standard are similar to control conditions or background conditions discussed in the design of experiments in the natural sciences, while other considerations are wholly unfamiliar or are similar to considerations from the social sciences rather than the natural sciences. For instance, insecticide is used on cotton plants to minimize insect interference with developing cotton bolls. NAWF measures the flowering date of the last bolls. Once the cotton plant stops producing bolls, insect control ceases to make an economic difference in the overall yield. On the other hand, Kentucky tobacco experiments need to be planted by June 20 because that is the latest date that commercial growers can plant tobacco and be guaranteed insurance on their crops. Only experiments performed prior to that date will provide useful information to growers as farmers are well aware that growing conditions following the June 20 cutoff are substantially different than those prior to it.

In this paper, we characterize grower standard as an epistemic object of agricultural science and use this characterization to illustrate a unique and institutionally-structured way in which agricultural experiments are value-laden. In Section 2, we define grower standard and argue that it differs from familiar epistemic objects in philosophy of science. In Section 3, we show that one important reason that grower standard differs from these more familiar epistemic objects is that grower standard is a product of interactions between research communities and agricultural extension workers. We explore the role extension work plays in the shaping of agricultural science practices more broadly and describe this role in terms of knowledge coproduction. Section 4 concludes.

1.1 Agriculture: a glossary

Agriculture remains an area of research less familiar to philosophy of science (but cf. Thompson, 2017). In order to help our readers navigate this new area, we begin with a brief glossary.

- *Agricultural practice*: the stewardship of crops and livestock.
- *Agricultural sciences*: studies of the cultivation of soil for the growing of crops, husbandry of animals, management of land systems, global and local seed economics, food scarcity, biofuels, and more.
- *Agronomy*: the scientific study of crops, soil, and plant ecology. Its focus is on crops of high commercial value for food, fuel, or fiber.[1]
- A*gricultural extension*: a formalized system of communication practices established between farmers, university researchers, and regulators to exchange ideas about new agricultural research, technologies, and practices.
- *Agricultural extension work*: activities that include digital and on-site consulting, attending local and regional grower/producer meetings, giving field day presentations, and carrying out experiments to improve agricultural practices. By participating in these activities, extension workers and farmers exchange information about how to improve production, increase crop diversity, provide nutrient support to soil, manage irrigation practices, and control pests and diseases.

[1] Agronomy is primarily informed by biological and ecological considerations and methods, its close connection to agricultural practices means that it is deeply entangled with technological, economic, commercial, and sociopolitical concerns. This entanglement is a motivating reason for our present interest.

- *Agricultural extension specialist*: an academic researcher[2] whose professional duties include both the production of scholarship and the performance of extension work (alongside teaching and service). While research and extension work are evaluated as separate categories, Extension specialists usually perform both types of work on a single research domain.

2. Grower Standard as Epistemic Object

2.1 Defining Grower Standard

An important component of designing agronomy research protocol is to identify and recreate what is known as “grower standard,” sometimes referred to as “grower standard practice” or “standard grower conditions.” Conditions that specify a grower standard can include fungicide, herbicide, and insecticide protocols; fertilization, watering, and harvest methods and timing; soil treatments; instrumentation used (e.g., cotton-picker, transplanter, tiller); and pathogen containment strategies. What counts as grower standard for a given experiment is particular to the crop, region, scale of production, and type of farming practice (e.g., organic v. conventional).

“Grower standard” is regularly referenced in descriptions of experimental design in extension-driven agronomy research. Designing experiments to imitate grower standard conditions is a distinctive epistemic feature of experiments in agronomy. Grower standard does not aim to recreate so-called natural conditions. In plant biology, e.g., laboratory conditions

[2] In the United States, extension work is carried out by employees of the Cooperative Extension Service (CES), both by *county extension agents*, who manage activities for a county, and by *extension specialists*, who are academic researchers. CES is an 18,000-person agency run by the U.S. Department of Agriculture.

usually imitate native settings for plant development, without an intention that the results of the experiment will be used to change that native setting. In contrast, extension-driven agronomy experiments aim to improve grower conditions. Experimental conditions are set up as a suboptimal baseline from which to improve production, rather than as a neutral background in which scientific phenomena occur. This difference suggests a different relationship between experiment and world than in natural sciences.

Some aspects of setting grower standard are analogous to fixing variables in experimental control groups. For instance, one goal of a recent plant-pathology experiment on grape powdery mildew (*Erysiphe necator*) was to determine the efficacy of a new strategy for fungicide application in which fungicide was applied after powdery mildew spores were detected by molecular assay, rather than according to growth benchmarks or calendar alone (Thiessen, 2016). In this experiment, the authors derive their results by comparing their protocol to the standard application procedure used by vignerons for treating grape powdery mildew. The standard application is described as a control plot and contrasted with the active “detection plot”:

> Control plot fungicides were initiated at 6 inches of growth or when a risk model indicated a high risk for spore release, and detection treatment plot fungicide applications were withheld until inoculum was detected or bloom had occurred [.] Subsequent applications of fungicides followed manufacturer recommendations for reapplication depending on chemistry. [...] After a fungicide programme was initiated, additional applications in both the control and detection plots were made using the grower's standard fungicide programme. (Ibid., p. 243)

The control plots appear to be treated with grower standard protocols as evidenced by the author's description of their own experimental results, stating: "no significant differences in berry or leaf incidence between plots with fungicides initiated at detection or grower standard practice plots." (Ibid., p. 238)

We make three further observations on this case in order to thicken our description of the grower standard concept. First, the notion of a control is used in at least two distinct ways in agronomy. The first is in the way exemplified above, where grower standard practices are taken to be a contrast class for experimental interventions. The second way is to define a control as an experimental plot that receives no or very few interventions. For instance, in the experiment above, Instead of treating the control plots according to grower-standard fungicide programs, the researchers could have generated control plots with no fungicide program. Setting a no-fungicide control for that particular experiment would not have been particularly informative, since the goal of the research was to test a proposed improvement upon current standard fungicide practices.

Second, the concept of a grower standard functions in this case in ways beyond merely setting a control group for the experiment. These functions are more difficult to categorize if what we are relying on is the existing philosophical language for experiment design. In the grape powdery mildew experiment, it is evident that the notion of a grower standard guides further experimental design considerations. The experiment tests when to initiate a fungicide program, but once initiated, grower standard specifies when and how future treatments will be applied. This is somewhat similar to the role played by background conditions.

However, the protocols that see the agronomic experiment through are often carried out by growers themselves. Agronomy experiments are typically carried out on either commercial or research farms. They are designed and implemented by researchers, and are maintained by farm staff whose backgrounds are in agricultural practice rather than agricultural science. These growers are active agents in the maintenance of grower standard practices, and their practical knowledge can inform the design of agronomy experiments.

Third, the grape powdery mildew experiment demonstrates quite vividly that grower standard is not a neutral backdrop for experimental intervention. Even though there are ways in which grower standard sets background conditions for the experiment, the whole aim of the experiment is to improve upon current grower standard practices for treating powdery mildew in Oregon grapes. In this way, grower standard is conceptualized as a suboptimal baseline upon which to build improvements.

This function of grower standard is not easily recognizable in common accounts of the epistemology of experiment. We believe this is due to the difference in aims between pure and applied scientific experimentation. In pure-science experimentation, central goals of experiments are to observe, measure, detect, understand, and control natural phenomena. For instance, in the experiment to test the effects of temperature and humidity on the proliferation of grape powdery mildew, Delp (1945) concludes: “temperature is the primary factor limiting the development of vine mildew” in the regions studied during the experiment. The results of Delp’s experiment might be (and indeed, were) taken up by agronomic experimenters or by growers in later efforts to improve growing conditions, but Delp's experiment was not framed around the investigation or improvement of grower standard.

While we do not wish to draw a hard division between pure and applied experimentation, we contend that when grower standard functions in an experiment in this baseline-setting way we describe, it does so in virtue of the applied aims of an experiment.

2.2 Grower Standard as Novel Epistemic Object

We have shown that grower standard is a complex and multi-functional concept within agronomy. It plays some familiar and some novel roles within the design and interpretation of agronomic experiments. The aim-setting and baseline-setting functions of grower standard distinguish it from both experimental controls and background conditions. We take this as evidence that grower standard is a novel epistemic object within the epistemology of experiment, that is, one that does not fit neatly into existing accounts of the phenomena and practices that comprise scientific experimentation or the epistemology of science more broadly. Grower standard is not a model, theory, instrument, type of evidence, or form of measurement. It also does not fit into the newer categories of epistemic objects suggested in recent accounts of the philosophy of scientific practice, such as Ankeny and Leonelli's repertoires (2016) or Currie's surrogate experiments and inference tools (2018).

Our analysis of grower standard shows that it is not only a novel epistemic object, but a novel *type* of epistemic object within the epistemology of experiment. For present purposes we resist the urge to name and characterize the broader category of epistemic object into which grower standard falls. However, we believe some generalizations can nonetheless be made about the sort of epistemic object that grower standard is by further investigating relations between the functions of grower standard and the network of scientific and extra-scientific influences that interact to produce grower standard. In the next section, we discuss the relationship between grower standard and agricultural extension work.

3. Extension Work and the Epistemic Objects of Agronomy

Above, we showed that grower standard provides a non-neutral set of background conditions for experiment, that it plays a role in setting the aims and methods of experiment, and that it is not a fixed standard but rather a suboptimal baseline to be improved upon through the results of experimental intervention. In this section, we show that the existence of grower standard as an epistemic object is inextricable from consideration of how it is used by different epistemic communities as a locus for interdisciplinary exchange. First, we show that the relationship between agronomy and agricultural extension work shapes the methods for knowledge production in agronomy. Then we extend existing accounts of interdisciplinarity in the philosophy of science to lay the foundations of a framework for understanding the knowledge coproduction that occurs through agricultural extension work.

3.1 Coproducing Knowledge Through Agricultural Extension Work

Agronomy and agricultural extension work are interconnected by important contingencies of history. In the U.S., agronomy research was integrated into the mission of a group of public universities designated as the Land-Grant Institutions (LGIs). One component of the land-grant system was to provide people an education that including agriculture, practical mechanic competencies as well as liberal arts and classics. The Hatch Act of 1887 created the agricultural experiment station program and the later 1914 the Smith-Lever Act formally associated extension work with the LGIs when it established the Cooperative Extension Service (See Footnote 2) to disseminate findings obtained from the experiment station's experiments.

The in-practice union of research and extension work means that while grower standard is *used* in agronomy experiment, it is *defined* and *known* through extension work. Growers know what grower standard practices are in practice, in their fields and with their soil. Their tacit knowledge may be shared when they show extension workers how they make decisions about when to fertilize, spray, harvest or till. Likewise, extension specialists can identify aspects of production, such as the importance of knowing that farmers will not take seriously the results of tobacco experiments planted in Kentucky after June 20, or understanding the economic impact on farmers if late-season insect control for cotton in Missouri is suspended too soon for a grower. This is one significant way in which extension work influences the epistemic objects of agronomy.

Epistemic objects like grower standard may be understood as a type of agricultural tool. Through extension work, agricultural tools can be shared, borrowed, invented, and innovated within local family farming communities, and in collaborations with research from multiple university extension centers. As with grower standard, farmers and researchers are often co-producers of these agricultural tools. These tools shape choices that farmers make about their farm and crops. For instance, given access to a mechanical seed corn harvester, a farmer might choose field corn whose ears grow at the same height facilitating more efficient picking. If a farmer has been no-tilling her operation, she might choose to plant a cover crop of ryegrass to build up the health of the soil, especially if she has fragipan soil (Vollstedt, 2020). Tool-driven knowledge of these techniques also shapes the type of extension research that is applied to crop production, as well as affecting decisions about which experiments on test fields are performed.

We contend that agricultural extension work plays an essential role in defining a new set of epistemic categories that are essential to the practice of agricultural science. Hearkening to contemporary work on social epistemology in the sciences, we call this process the *coproduction of knowledge in agricultural science*. Importantly, the epistemic objects produced through this process are of use to both individual researchers and farmers as well as to wider populations. Further, these epistemic objects impact all of us by affecting decisions about how our food, fuel, and fiber is made.

Focusing on the knowledge-coproduction relationship between extension researchers and farmers allows us to shine a light on a central method of knowledge growth in agricultural science. We contend that this method can only be understood within the realities of extension's institutional and demographic history. As such, our nascent epistemology of agricultural extension complements current philosophical work on the contingent and value-laden epistemologies of other scientific practices. Because extension is also a formalized federal institution, we also see a particularly strong connection with current work that investigates the interplay between political and institutional pressures in shaping scientific research (e.g. Brown 2013, 2013b; Douglas, 2009; Kellert, Longino, and Waters, 2006; Kitcher, 2003, 2011; London and Zollman, 2010; Zollman, 2007).

Agricultural extension work is fundamentally an exchange of ideas between extension professionals and the communities they serve. Our analysis of the concept of grower standard shows that this exchange shapes the epistemic categories of agricultural science in an applied and interactive way. Agricultural extension has played a unique role in shaping rural and agrarian attitudes toward science. These attitudes are complex and varied, insofar as scientific innovation has greatly increased agricultural productivity, but also changed the farmer's relationship to technology, business, and state interests over the past century. Through technological innovation, it has also contributed to a diminishing agricultural. This is fertile soil for new philosophical analysis of the relationships between science, agriculture, and society.

3.2 Knowledge Coproduction in Agricultural Extension Transcends Interdisciplinary Exchange

Extension originates important epistemic objects of agricultural science, such as grower standard. But extension work is not just limited to the exchange of research and applied scientific knowledge from researcher to farmer and farmer to researcher. Extension work maps a space of communication where knowledge grows: it is the epistemic locus where a specific and impactful variety of knowledge coproduction among diverse stakeholders takes place. A robust characterization of the epistemic objects generated in extension work thus requires a deeper understanding of the standpoints of these different stakeholders, their interests, and their interactions.

It would be impractical to generate a complete taxonomy of stakeholders in extension work and agricultural science, but it is worth mentioning some common entries to illustrate the diversity of standpoints influencing the generation of epistemic objects like grower standard. We have discussed extension specialists and farmers at length already, and we have shown how farmers' interests shape grower standards. Analogous stories can be told about the interests of farmers' suppliers and consumers, as well as about institutional and funding pressures on the research programs of extension specialists. Additionally, extension work is also performed by county extension agents, whose professional obligations to research differ significantly from extension specialists, and whose training and interests likewise differ. These are all stakeholders in the shaping of epistemic objects in agricultural science.

Often, the ability to form research questions and pursue research depends on the epistemic aims and values of stakeholders within a particular agricultural environment (Bammer et al., 2013, 29-54; O'Rourke, Crowley and Gonnerman, 2016, 62-64). When philosophers have previously studied the production of epistemic objects through the collaboration among diverse stakeholders, they have primarily done so through the study of interdisciplinarity. Foundational philosophy-of-science work on interdisciplinary exchange frames interactions between disciplinarily divergent members of a scientific project as an economic exchange, specifically a "trading zone." (Galison, 1997, 1999) The metaphor is extended into linguistics by arguing that just as trading communities with different languages developed pidgin vocabularies to exchanges goods, so do scientists in different disciplines generate limited common vocabularies for the exchange of ideas, based in interactional expertise (Collins et al., 2007).

Extension work constitutes and is constituted by an interdisciplinary exchange insofar as it is knowledge that is articulated within a framework built from interactions and in-practice experience that both shapes and is shaped by future interactions. However, extension work also seems to outstrip the notion of interdisciplinary research, due to the diversity of interests and backgrounds across stakeholders. Unlike other loci of interdisciplinary discussion, the boundary that is crossed is not just disciplinary. In extension's attempt to understand the goals and purposes of another on their own terms, what is required is more than an understanding of the position of the farm, choice of crops, and agricultural goals.

Within extension work, knowledge is always understood with reference to a particular context and in light of the actions of a number of epistemic agents. The circumscription of an epistemic object relies on how farmers use standards and tools, how these are developed in industry, the purposes for which they are used, and how each of these characteristics are informed by research within agronomy. Their use shapes diverse perceptions (within industry, university, farmer, and among consumers) and may vary depending on the crops (e.g. cotton, maize, wheat); the relationship between farmer, farm, biotech industry, society, and the environment; the interpretation of languages relied upon by farmers and scientists; and how research, technologies, and applications affect perceptions about "nature" and "cultivation." That is, an epistemic object in extension relies on a number of positionalities within academic research knowledge, applied scientific knowledges, technological knowledge, and local ecological knowledges.

Further, within extension, interactions are not limited to agent–agent interactions but include agent–object interactions as well. Knowledge coproducing interactions within extension work include researcher–farmer; farmer–veterinarian–livestock; agronomist–agrotech–banker; farmer–land; farmer–cotton baler–farm financial officer; agronomist–agricultural science research standards–university interactions; and many more. These interactions vary depending on the crop, pest, and consumer. For instance, cotton production requires substantial up-front costs (e.g. pickers, balers), but may require less irrigation than maize. Maize may require extra irrigation around the time of tasseling. Farmers planting maize may also consider whether they will sell their crops for ethanol production or food production considering the position of the consumer and other local and global markets. In these discussions, both farmers and extension researchers are beneficiaries of the knowledge that they coproduce.

While some philosophers and historians of science have accounted for the clustering of cross-disciplinary knowledge creation around instrumentation (e.g. Mody, 2011), few have developed an account that encompasses agent–agent interdisciplinary exchange, tacit-knowledge exchanges, and what is commonly called “instrumental knowledge.” Because of the diversity of expertises and interests involved in knowledge coproduction in extension work, any epistemology of extension must incorporate all these sources of knowledge-growth interactions under a shared umbrella. This sets the knowledge-making activities of extension work apart from other sorts of knowledge-making practices in the natural sciences, and the epistemic objects created by this means are likewise distinct. Inherently defined by the ineliminable role of extension work, agronomy regularly generates epistemic objects of this experimental and interactive sort.

4. Conclusions

Knowledge coproduction in extension work and agronomy is not the result of simply applying universal rules for deriving knowledge from facts. Instead, it is the result of critical intersubjective modes of investigation between farmer and extension worker, and between farm, academy, and society. In order to illustrate what knowledge coproduction looks like within extension work, we introduced the concept of the grower standard as an example of a coproduced epistemic object. The purpose of this was to show how knowledge is obtained through the activities of extension and communication between different stakeholders (e.g. researchers, farmer, industry, state). We showed how this form of knowledge coproduction was dependent upon these reciprocal channels of communication, and also how it transcends familiar transactional accounts of interdisciplinary research.

Although we have argued that the sorts of epistemic objects that arise from extension work are different from those arising in other disciplines, we also see strong connections between our work and other contemporary discussions in philosophy of science. In addition to literatures on interdisciplinarity and values in science, our account of grower standard as an epistemic object—as a tool that shapes and is shaped by the knowledge-making practices among a host of stakeholders—has roots in a number of different philosophical accounts of knowledge creation, including integrated history and philosophy of science, technosocial philosophy, and experimental and perspectival approaches to realism.

These authors provide motivation for our work by taking seriously the study of the interaction between humans, machines, and tools. In their views, and in ours, these interactions are the remit of a more widely extended approach to the study of philosophy of science that not only recognizes the social aspects of scientific knowledge production but sees them as ineliminable to knowledge and its growth. This approach informs the kinds of knowledge coproduction that take place within extension. In future work we hope to both jointly and individually pursue the relation between our views and these influences.

In particular, one of us will develop these foundations into a study of the normative constraints imposed on knowledge coproduction by the interests of the diverse stakeholders in extension work. This will focus on work on the intersection of history of science, science and technology studies, and philosophy of science. Meanwhile, the other aims to compare the particularities of knowledge coproduction in extension work to knowledge coproduction in other applied sciences. As an applied science that has been historically coupled to institutional channels for communication with lay communities, the broader structure of knowledge construction in agricultural science is unlikely simply to fall in step with the structure of knowledge construction in the natural and social sciences.

We both think that the aim-setting and baseline-setting functions of grower standard also illustrate how deeply the applied aims of an experiment can be integrated with the methods of the experiment. Now-outdated views about the value-free ideal of science would suggest that this degree of integration makes for bad science, in that the data produced by the experiment are inextricable from the epistemic object of the grower standard. In future work, we will show that this degree of integration is instead an asset to agronomic experiments.

In this paper, we have provided a proof-of-concept sketch of what an epistemology of agricultural extension work might look like through our analysis of (a) grower standard as epistemic object and (b) stakeholder-driven coproduction of agronomical knowledge. We argued that agricultural science is the result of historical, social, interactive, and highly contingent agricultural practices and how the epistemic objects it produces are inextricable from those contingent histories. The example of grower standard was meant to elucidate how considerations of value are constitutive of an epistemology of experiment in agricultural science. We do not see agricultural science as an outlier, but as an archetypical instance of value-laden epistemologies in applied sciences. As such, the purpose of our paper was to prepare the ground for future work exploring this new form of value-ladenness in the methodology of agricultural science more generally.

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