Design as a source of renewal in the production of scientific knowledge in agroecology

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1 – Introduction

Innovation has become crucial in the strategic orientations of agricultural research institutes, and is declared as critical for future agriculture to meet the challenges raised by societal expectations. This emphasis on innovation requires to orientate agronomic research to design or design-support studies (Klerkx et al., 2012; Prost et al., 2016; Salembier et al., 2018), which contrasts with a persisting "academic polarization" (Bonneuil and Thomas, 2009) and a widespread view of innovation as resulting from the aggregation of available scientific knowledge. In these design studies, agricultural researchers do not aim primarily at producing knowledge that describes the world as it is, but rather at designing tools, methods and processes that support the actions of farmers or their advisors to achieve desired farming systems. Moreover, *Design Studies* show the existence of close links between design and knowledge production, (Eekels and Roozenburg, 1991; Hatchuel and Weil, 2009; Owen, 1998). In agronomy, various studies question the knowledge that supports these design processes (Berthet et al., 2015; Duru et al., 2015; Toffolini et al., 2017), but little consideration is given to the scientific original knowledge that is generated during design processes. Based on a cross-analysis of empirical cases in which agricultural researchers have designed innovations with a diversity of actors from agricultural sectors, we analyzed the production of scientific knowledge that takes place during design processes.

2 – Materials and methods

Nine case studies were chosen among design projects in agricultural research (agronomy, population genetics, ecology) oriented towards agroecology. Case selection was based on four common criteria: (i) the expression of an *initial design intention*, (ii) one (or several) *product or process innovation(s)* of farmers' activity (e.g. crop management routes, cultivar mixtures, decision support tools, spatial organizations of agricultural landscapes); (iii) *scientific papers* on knowledge produced as part of the design process; (iv) the possibility of easily collecting information through interviews of the project main actors. The cases covered a diversity of (i) duration of the design process (ranging from 3 to 15 years, still in progress or completed), (ii) the farmers'actions targeted in the use of innovation, and (iii) the spatial scale (from field to territory).
Each case study combined semi-structured interviews with the scientists involved in the design process, and document analysis (research project, workshops reports, articles).

We traced back the design process from the resulting innovation to the initial design intention, identifying the knowledge produced during the design process and analyzing the resources mobilized, the formulations of initial ‘desirable artifacts’, the research practices, and the agricultural situations that host the innovation process.

3 – Results – Discussion

None of the innovations studied resulted exclusively from the application of pre-existing knowledge, but all design processes generated new knowledge concerning agro-ecosystems. Knowledge produced concerned: i) biological or physical processes of the agro-ecosystem (e.g. the dispersion distances of pollen beetles, during the design of landscape schemes for low-pesticide rapeseed), ii) effects of technical actions on the agro-ecosystem (e.g. the impact of mass selection on genetic diversity and adaptation of population varieties during the design of a wheat participatory breeding scheme), iii) cognitive models integrating key biophysical and social processes and allowing action management (e.g. modelling the direction of water flow at any point on a plot as a function of tillage direction and field slope, during the design of crop mosaic at watershed scale mitigating erosive runoff). Thus even if innovation itself is not always generalizable beyond the contexts in which it was produced, its design has led researchers to produce more generic knowledge about agro-ecosystem entities and processes.

Then we showed that the scientific knowledge produced was partly contrasting with the dominant knowledge in each field. It either concerned new or previously ignored ‘agricultural entities’ (e.g. the rape’s frozen leaves when designing a spring fertilization strategy), or new forms of action (e.g. the direction of soil tillage when modelling the runoff). In our case studies, the knowledge produced was thus consistent with renewed representations of agroecological processes or farmers’ actions.

A temporal analysis then showed that, in each case, the desirable artifact was evolving throughout the design process, and the produced scientific knowledge was both resulting from the formulation of a desirable artifact and inviting to reformulate it. For instance, in a case study concerning rapeseed, the first formulation of the desirable artifact was “a low-input crop management route for rapeseed”, limited to the plot scale. The knowledge produced, namely about the significant impact of pollen beetles on crop production, changed this representation to include the landscape mosaic, and interactions between rapeseed plots at landscape scale. The desirable artifact then became a landscape indicator assessing the probability of high pollen beetle pressure not regulated by parasitoids. This led to the production of new scientific knowledge on the dispersion distance of pollen beetles. We observed such reformulations in all case studies. Such iterative processes are described in design theories, which model the relationships between the evolution of the specifications of new concepts and the production or reorganisation of knowledge (e.g. Hatchuel and Weil, 2009). The evolutions of the desirable artifacts are not progressive specifications of characteristics of the artefact but also redefinitions of what is desirable. The production of knowledge contributes to this redefinition, by changing the representations of the agroecological processes.

Finally, we revealed three types of drivers for these co-evolutions of the desirable artifact and the representations of the agroecological processes. The first one was the identification of scarce “singular” situations that reveal a weakness in available artifacts, and lead to the reformulation of a desirable artifact better suited to these situations (e.g. stony soils which make it impossible to measure inorganic N soil content, and therefore to calculate a N fertilizer rate). The second one corresponded to diagnoses of the diversity of impacts of practices or of practice contexts (e.g. during ideotyping workshops of variety mixtures, farmers and advisors based blending strategies on variety traits other than those identified at the start by the researchers). The third driver was the early experiments with first prototypes (e.g. during the design of vegetable cropping systems, the experiment of intercrops led to identify the unexpected outcomes of temporal and spatial organisation of species in a tunnel).

4 – **Conclusions**.

Our study shows that design processes renew the production of scientific knowledge. Some knowledge generated during design processes is generic in scope, even when the situations in which design processes take place are local and specific. We show that confrontation with situations of action plays a key role in guiding the design process and, in turn, in the production of knowledge. Engagement in a co-design process can thus be seen as a research practice that leads to the production of original knowledge, where the ways of knowing of a greater diversity of actors can be taken into account.

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