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Contextualizing Engineers' Participation in Socio-technical Networks of Design

Abstract

The role of research centres in generating new technology for development is problematic as engineering is no longer an isolated field of human activity. Rather than providing a clear-cut solution, this paper makes the case for the inclusion of this problematic area into research activities and technology-design procedures. In rural development, the classic notion is that of agricultural extension, an organisation that disseminates scientific knowledge and technology. STS provides a different understanding of what extension means. The notion of the lab or studio as the single source of knowledge is an after-the-fact creation, once the network linking labs and farmers has been stabilised (Latour's point). Based on this alternative understanding, there are two major responses. One focuses at the lower end of the connection, emphasizing the role of users (farmers) and the need to create a participatory learning process. The other response is focused on the top-end, emphasizing collaboration between various partners in the innovation process and the need for system learning. Both responses are highly procedural with the risk of losing sight of the importance of the material, technical and skill factors that have a major effect on who can participate and what type of interactions can be effective. What is needed is a case-by-case approach and the inclusion of basic lessons from STS and anthropological accounts. We illustrate this through the introduction of forage choppers in Uganda. This case shows that there is a need to establish a functional connection between the production of knowledge and technology in research centres and the production of knowledge and technology at the field level.

Introduction and main argument:

The design process is one important locus where technical issues of technologies have an influence on broader social issues. Although engineers are in most cases fully aware of the technical issues during the design process, Cañavate et al. (2009) have criticized them for their lack of attention to the social implications of their work. In conceptualizing the process of technology design, Poel and Verbeek (2006) have argued that social reflection during the design process would allow the anticipation of technologies-in-design in their use context. But a mere reflection on the design process is not enough to ensure that the design process turns out workable tools/machines. Since engineering is no longer an isolated field of human activity

(Mazher 2002), this has made the role of research centres in generating new technologies for development rather problematic. Rather than providing a clear-cut solution, this paper makes a case for an inclusion of this problematic area into research activities and technology-design procedures.

In rural development, the classic notion is that of agricultural extension, an organisation that disseminates scientific knowledge and technology. Science and Technology Studies (STS) provides a different understanding of what extension means. The notion of the laboratory or studio as the single knowledge source is an after-the-fact creation, once the network linking labs and farmers have been stabilised (Latour's point). Based on this alternative understanding, there are two major responses. One focuses at the lower end of the connection, emphasizing the role of users (farmers) and the need to create a participatory learning process. The participatory approach though has not encompassed the entire technology development cycle; mainly focusing on participatory needs assessment and participatory evaluation of finished technology with minimal or no input at all from the users during the design of interventions. The focus should be on allowing users not only to evaluate the tool during the design process, but to work with it, re-construct it within their social, economic and cultural contexts to turn out a stable design that works for users. The other response is focused on the top-end, emphasizing collaboration between various partners in the innovation process and the need for system learning. The approach recognizes that design is a collaborative effort in which many people (engineers, technicians, users) play a role (Poel 2001) in varying institutional or social environments. However, the presentation of society (users) during the design stage is quite poor (Cañavate, Casasus et al. 2009), with their involvement very often confined to institutionally configured spaces.

Both responses are highly procedural with the risk of losing sight of the importance of the material, technical and skill factors that have a major effect on who can participate and what type of interactions can be effective. What is needed is a case-by-case approach and the inclusion of basic lessons from STS and anthropological accounts. We illustrate this through the introduction of forage choppers in Uganda. The need to review the approach to technology design which arose from the recognition of frequent failures in technology development (Sørensen and William 2002). The unintended technical and social outcomes of technology initiatives and the complexity of social interactions around the development and use of technology also played a part. Consequently, the STS focus on design has proposed "design by society" as a conceptual approach for examining, among other things, how societal values are built into the world by design (Woodhouse and Patton 2004).

The user-centred vis-à-vis the design-centred mode of technology development has been an issue of debate in the field of STS (Stewart and William 2005; Dong 2010). The user-centred approach places users at the centre of the design process from the stages of planning and designing system requirements to implementation (Baek, Cagiltay et al. 2008). On the other hand, the design-centred approach, the design of the artefact is more or less a simple reflection of the values and priorities of designers (Stewart and William 2005), with users seen only as passive recipients of the technology and its embedded values (Sørensen 1994).

Steward et al. (2005) argue that unlike the design-centred mode of technology development, where users' relations are presumed by technology producers, the design decisions of the user-centred approach are much more likely to reflect values and desires of users. Dong (2010) also emphasizes that the user-centred approach prevents designers from seeing themselves as "solution providers", and allows them to appreciate user capabilities, needs and expectations. Stewart and William (2005) have extended the user-centred approach beyond the design process itself to the process of using the tool, and referred to it as the "social learning process". They argue that social shaping offers an evolutionary model of how societal requirements and technological capabilities might be coupled together. This approach assumes that the tool is "unfinished" as it lands among users, and it is the interaction with users that leads to a stable design. In this paper, we argue along the same lines in reviewing the introduction of the forage chopper among smallholder dairy farmers in Uganda.

Background of the project:

The desire to improve household food security and empower women in rural households has seen the implementation of various agricultural projects, particularly livestock initiatives targeted at women smallholder farmers (Walingo 2009). These livestock development projects generally seek to empower women by improving their incomes and nutrition, and the nutritional status of other household members. In Uganda, a number of livestock projects have supported women by providing zero grazing dairy animals, where the first beneficiary of the project passes on the first calf to another woman as a means of multiplication and distribution (Baltenweck, Mubiru et al. 2007)

In zero grazing, animals are permanently confined in a cattle shed and fed on fodder cut and carried to them daily (Baltenweck, Mubiru et al. 2007; ILRI 2008). This livestock production system is characterized by high feed requirements and high labour demands (Kabirizi and Nanyeenya 1998). Forage processing for zero-grazing animals requires planting and caring for forage just like the other seasonal crops, and then harvesting, transporting home, chopping and feeding it to the animals. Forage materials for zero grazing animals require chopping for ease of consumption by the animal and increased palatability. These activities are predominantly carried out by women, often assisted by their children. Given this increased burden, it has been imperative to enhance women's access to appropriate technologies and necessary information regarding new forms of livestock husbandry. The intention of this is to maximize the efficiency of scarce labour time, and to guarantee that women and their families benefit directly in terms of improved welfare.

The high labour demands, coupled with a lack of sufficient land for forage production and forage scarcity for dry season feeding, means that available forage must be efficiently used, and waste minimised (LSRP 1999). Hand tools and head porterage are factors in the labour demands of forage production and transportation to often distant cattle stalls. Hand chopping is the common practice among the majority of farmers. In addition to low output capacity and lack of uniformity in length of cut, the method is tedious, time consuming and quite dangerous for the operator. To address some of these constraints the National Agricultural Research Organization (NARO) has developed two types of mechanized forage chopping, motorized and manual. The manual chopper has become more popular with farmers owning a few animals since both initial and operating costs are much lower than for the motorized chopper (Lubwama, Candia et al. 2003).

Photo 1: Motorized forage chopper

Photo 2: Manual forage chopper

Photo 3: Traditional chopping

The origin of the 'problem' and how NARO came to a solution

The development of the forage chopper originated from the interaction of researchers with zero grazing farmers around the Centre during a biogas project (AEATRI 1995; AEATRI 1997; AEATREC 2000). Its introduction in the Masaka district, however, followed a diagnostic survey by the Livestock Systems Research Program (LSRP) in 1998/1999 (LSRP 1999) under NARO. During the diagnostic survey, smallholder dairy farmers in Masaka identified feed shortage for dairy cattle and drudgery presented by high farm labour demands as major constraints. Lack of sufficient land for forage production coupled with forage scarcity for dry season feeding and labour shortages necessitated efficient use of available forage by minimizing its wastage.

After prioritizing the constraints, different intervention options were screened on how to improve feeding resources, promote forage conservation and reducing drudgery associated with forage chopping. The development of the forage choppers was purely adaptive research. The initial working design of the manual forage chopper was acquired through AEATREC's collaborative work with Sokoine University of Tanzania. Whereas farmers were involved in the needs assessment and prioritization process, they were not represented in this planning of interventions. In other words, the users did not participate in the planning of the intervention. The effect of this emerged during the domestication process of the machine when it was released to the users.

The initial design of the manual forage chopper (Photo 2) was an all-metal frame, with an open frame base and a lever operated panga attached to one end. The researchers assessed the performance of this design using computer models. With the open frame base, some of the unchopped material could either easily pass through or fall off from the sides, requiring collecting now and again, which prolonged the time required for the chopping activity. The open end at the panga slot also meant that users could easily push their hands too close to the panga, thus posing the danger of accidentally cutting one's fingers, as in the case of traditional hand chopping. This original design also had no means of controlling the length of cut that researchers deemed necessary to minimize forage wastage.

Photo 4: Design used in adaptive research

The standard NARO design (Photo 5) comprises of the following modifications: metal holding tray to minimize the falling of unchopped forage, safety hand guard to prevent the operator's hand from reaching the panga, plate controlling length of cut for pre-setting the length of chop, and adjustable panga position to accommodate both right-and left-handed operators. The lever operated mechanism of the panga was retained. Given the weight of the holding tray, the stand was redesigned to offer better support for the holding tray as well as to increase stability of the machine during operation.

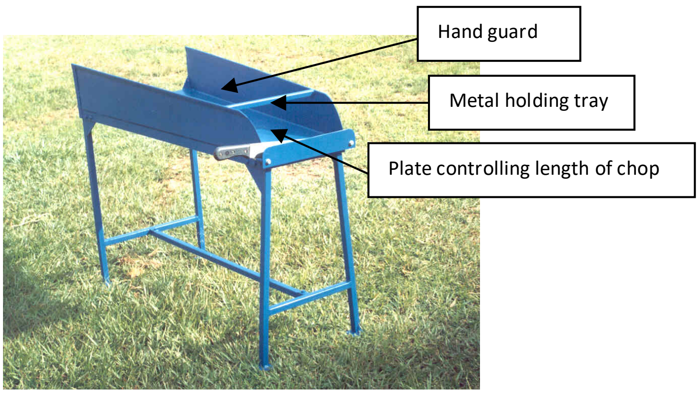

Photo 5: Improved NARO design

Introduction and organisations involved

The Masaka district used to be Uganda's food basket, but it is one of the districts which suffered earlier from civil war, poor governance, epidemics and total collapse of the service delivery system. This bad situation resulted in the decline of Masaka both socially and economically between 1971 and 1985 (MDLG 2007). Most former local administrative structures were destroyed in the chaos and the few which survived were highly dilapidated. In an effort to escape poverty, men and youth pursued the urban migration pathway towards off-farm employment and education which severely reduced the agricultural labour force, slowing recovery and adding burdens on women. In the post-conflict reconstruction process several NGOs came up with agricultural programmes to help revive the district. Two noteworthy agricultural non-governmental organizations for the livestock activities were Send a Cow (SAC) and Heifer Project International (HPI).

Send a Cow Uganda (SACU) was introduced in the Masaka district in 1999 by the proprietors of the St. Jude Family Training Centre with the intention of improving women's welfare in the household, hence contributing to improving family livelihoods. Heifer Project International (HPI) was introduced to Masaka in 1993 by the Masaka Diocesan Development Organization (MADDO), a Catholic church-based organization. In the effort to resettle farmers in a socially and economically drained district, the NGO interventions targeted rural women. In order to enable women to attend to both their reproductive and productive roles in the confines of their homes, the NGOs introduced exotic zero grazing cattle to enable women to generate an income on-farm. Both NGOs used the farmer group approach, re-organizing farmers into formal working groups for training purposes and targeting of interventions with an emphasis on women farmers.

The introduction of zero grazing animals by Send a Cow (SAC) and Heifer Project International (HPI) set into motion a mechanism that required women to access more technologies to effectively benefit from the project. The role of the first NARO project was to increase feed resource availability. Establishing fodder banks and leguminous forage were the two interventions targeted to increase feed availability. The second NARO project of addressing efficient forage utilisation followed immediately after the first phase of establishing fodder banks. This project targeted forage processing and conservation. The forage chopper then became immediately relevant to the smallholder dairy farmers for forage processing and conservation as means of efficient forage utilization. Its introduction among the smallholder dairy farmers was based on the treatment selection/allocation criteria of the farmers that were involved in forage conservation. Only eight households selected for the conservation of forage received the forage chopper as an incentive to facilitate the conservation technology.

Variation and adjustments to the chopper

New technologies are often threatening and challenging, so that to be incorporated in our lives, they must be successfully "domesticated" (Bray 2007). The term "domesticated" is used here to apply to the process through which a new device is "tamed" or appropriated within domestic space (Stewart and William 2005; Williams, Stewart et al. 2005; Bray 2007; Oudshoorn and Pinch 2008). It serves to highlight internal negotiations, challenges to power and control accompanying adoption of the device (Stewart and William 2005; Williams, Stewart et al. 2005). New machines have to be transformed from being unfamiliar and possibly threatening into familiar objects embedded in the practices and routines of everyday life (Lie and Sørensen 1996). The processes of integration and interpretation of a machine are therefore usually influenced by social structures, circumstances and cultural conceptions of households. Interplay of the machine with these relations shapes the process and outcome of technological change.

In the domestication process of the forage chopper, various forms of usage were observed, entailing elements of adjustment and copying. Three groups were recognized: users, former users and non-users. This paper focuses on these three groups, in order to understand usage issues, how farmers mobilized community resources to facilitate the process of making, and why in some situations farmers opted not to engage with the technology. Usage comprised two aspects - making and remaking. The process of making entailed the mobilization of community resources (technical services, materials of fabrication and after sale services). The process of remaking entailed adjustments and modifications to the introduced the machine to make it workable for users. Materials of fabrication changed, variations in the size of the machine emerged and a range of coping mechanisms was devised either to accommodate specific needs/requirements of heterogeneous users or to address issues of after sale services.

Table 1: Distribution of usage and former use

Model/Type	No. of households	Users	Former-users
NARO model	8	3	5
NARO reproduced model	2	1	1
Various all-metal models	12	9	3
Metal / wooden models	8	7	1
Wooden models	5	4	1

The use of the NARO forage chopper involved diverse aspects of the remaking process, with users adjusting it to their needs and availability of resources. The adjustments made (Photo 6) included: removal of the plate controlling length of chop (a); replacement of standard parts with readily available spares (b); the facilitation of its use by children (c).

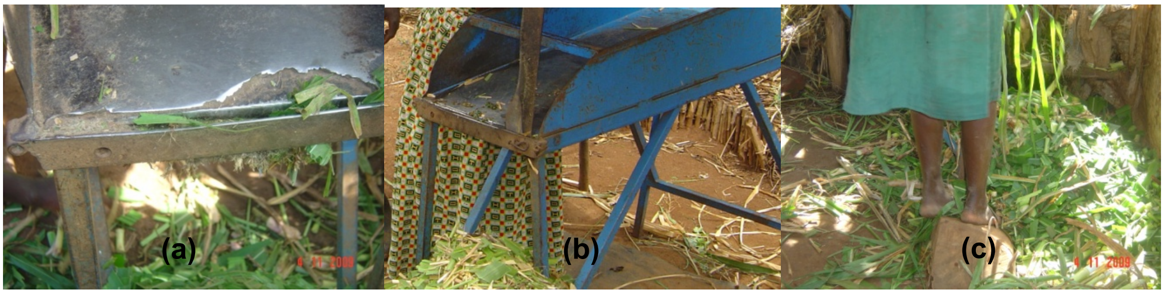

Photo 6: Adjustments for the NARO model

Whereas the length of the cut defined the designers' notion of effective chopping, users were simply concerned with reducing forage to sizeable pieces without necessarily paying strict attention to the exact length of the chop. The frequent blockage of the panga slot, especially when high moisture content legumes were mixed with Napier grass, was the major reason for removal of the plate to ease access to the slot for cleaning purposes. A simple adjustment of removing the plate shifted the emphasis of operation from uniform length to speed. In spite of the designer's notion of using standard parts that could easily be sourced, when users were faced with damaged bolts, nails formed a good substitute that allowed continued use. Children are an important part of family labour enrolled for forage processing. However, the height of the NARO model does not favour their operation, hence the need for a stepping block (Photo 3(c)) to ease the operation. All these user adjustments mean that in the design of labour-saving tools designers need to be well informed about user preferences as well as have a clear understanding of the users' notion of efficient utilization of the machine.

The making process of the forage chopper resulted into a number of variations in the models, ranging from the reproduced NARO model to a small version of an all metal design, a combination of wood and metal and the wooden model (Photo 7).

Photo 7: Variation in forage chopper model: (a) Reproduced NARO model; (b) Reduced all metal model; (c) metal/wooden model; (d) wooden model

Emphasis on technical efficiency resulted in the use of high cost materials, pushing the cost of the finished machine too high for some farmers could not afford. Farmers engaged local welders in reproducing the NARO model using photographs as "blue prints". Aside from reproducing the NARO model, the making process took on other design formats, varying in materials selected (metal sections, scrap material and wood), design and dimensions to accommodate user needs and requirements. Welders still formed a very important resource that facilitated the making process, with farmers playing varying roles in the technology development process depending on the fabrication material.

Paying for a finished product or providing raw materials and paying for the labour of fabrication was common for all metal machines. The involvement of users in the fabrication process was a result of introducing wood into the design that moved part of the fabrication process on-farm. The evident reduction of materials used for fabrication either with a reduction in the size of machines or the use of an open base instead of a solid one was common to all machines. There were variations in materials of fabrication as well. This all had a direct bearing on the cost of the finished machine and its portability. It is evident from these variations that quality alone is not enough to justify the cost of the machine to farmers, affordability counts. Over and above the cost, the ease of moving the machine was also important for users. As in the case of the users of the NARO design, farmers made several adjustments/modifications to the other designs to improve machine performance (Photo 8).

Photo 8: Users' modifications: (a) delivery sheet to feeding trough; (b) open base machine secured to collecting box; (c) wooden extension to hold unchopped forage; (d) wooden stepper to accommodate varying heights of operators.

Irrespective of the source of the machine, all these modifications point to the fact that there is no "ready to use" machine. The varying farmers' roles in technology development demonstrate the users' ability to mobilize local resources to address their needs. It emphasizes the importance of technology designers being well informed about user contexts, because this context defines what they can or cannot afford.

Gender/household effects: former users and non-users

The failed remaking process resulted in the emergence of former users that were characterized by either rejection (those who discontinued use voluntarily) or expulsion (those who stopped using the technology involuntarily) as shown in Table 2. Out of the 35 households initially having the forage chopper, 11 households abandoned its use. Their rejection of the machine was attributed to either poorly designed (inefficient) machines or wrongly selected (inappropriate) technology. Low quality materials and poor fabricating skills resulted in poorly designed machines that were difficult to operate. Many fabricators relied on photographs or sketches that farmers had made of the different machines they had come across, without necessarily seeing the machine physically. Besides, fabricating agricultural tools was not their mainstream work.

Apart from poorly reproduced designs, the low output of the machine given the herd size made it inappropriate for farmers in excess of three animals. The manual forage chopper was designed for farmers with not more than five animals, three being the ideal. However, there were cases of farmers with more than five animals who had acquired the machines without this kind of information, only to realize that using the machine did not save them any time. As a coping mechanism, those who rejected the machine resorted back to the traditional hand chopping method and/or semi zero grazing.

Table 2: Distribution of former users

Model	**Expelled**			**Rejecters**		**Total**
	Spares	**Dead animal**	**Changed enterprise**	**Inefficient**	**Inappropriate**	
NARO model	3	1	1			**5**
NARO reproduced				1		**1**
All-metal models	1		1		1	**3**
Metal and wood		1				**1**
Wooden models				1		**1**
Total	**4**	**2**	**2**	**2**	**1**	**11**

The expelled category had stopped using the technology involuntarily because of cost or lack of spares, death of the animal, or changed enterprise. A lack of spare parts accounted for the largest number of expulsions, but it was confined to households that had acquired the metal model. With the mode of operation of the livestock NGOs where the selection criterion does not permit former beneficiaries to qualify for another animal right away, the death of a cow meant that the machine was redundant in these households. Aside from the death of an animal, the sale of an animal and the shift from zero grazing to free range system also made the forage chopper redundant in two households.

The former usage was largely framed by access to information regarding the relevance of the machine and technical after sale services, the availability of spares and sustainability of the zero grazing animals' enterprise. Studying former usage reveals the constraints in user-producer interaction, highlighting poor technology information flow and the weak link of community-based repair and local manufacturing services. This is another example that points to the need for clearly understanding how different elements of the same technological system combine or influence each other and how farmers mobilize them to provide solutions.

In spite of the encountered usage, there were farmers who did not take up the forage chopper. Of 30 households sampled without the forage chopper, six (6) farmers never used the forage chopper because they never wanted to (resisters) and twenty-four (24) farmers never used the forage chopper, because they could not get access to the technology (excluded) (Table 3). The use of the forage chopper was resisted for two reasons: cheaper alternatives and ineffective technology. Readily available production labour force, the low cost of hired labour compared to the investment in the machine and ability to combine zero grazing with free range grazing (use of the semi-zero grazing system) were cheaper options for some farmers than incurring the cost of the machine.

Table 3: Distribution of non-users

Household type	Resisters		Excluded			Total
	Inefficient	Alternative	High cost	Limited info	Scarcity	
Male headed	1	4	13	4	1	**23**
Female headed			5	1		**6**
Female managed		1				**1**
Total	**1**	**5**	**18**	**5**	**1**	**30**

Source: Research data (2008)

The issue of the forage chopper not saving sufficient time was indeed raised by some of the former users. This is an indication of varying user assessments of the machine and developers, and raises a question about the specification of the exact context in which a technology indeed saves labour. The second category of non-users were the excluded farmers, who had never used the forage chopper, because of the prohibitive cost, limited information reaching farmers regarding the machine (especially its source), and lack of readily available machines in some farmers' localities.

The high numbers of non-users citing high cost in male-headed households has two implications. Either where men-controlled income allocation, labour saving technologies were not a priority when allocating household resources, or where women-controlled livestock generated income, it was too low to cover all livestock generated expenses. In light of limited resources to allocate, farmers are bound to be more discriminating in what technology they invest in and will endeavour to adjust to necessity, but within the constraints of available resources. Not knowing how to use or source forage choppers was observed among farmers who were not beneficiaries of donor projects, because they were persistently left out of livestock development related training. Exclusion was further aggravated by the uncoordinated efforts of different actors to address smallholder dairy farmer constraints, coupled with limited focus on agricultural engineering technologies by most intervention agencies.

The role of local blacksmiths

The making process of all the metal machines required welding services. Unlike the NARO workshop with technicians trained to handle fabrication of agricultural machines, farmers in Masaka only had access to local welders. The reproduction of the NARO model in two households was done by a local welder using pictures that the farmers had taken of the initial design as one farmer narrated:

> I carried a photograph of the NARO machine to a welder and asked him to reproduce it. It was not intentional to make it short to accommodate the children although it eventually worked in my favour. The welder did it to economize on the materials used. (farmer interview, 2008)

Characteristic of all the other households where other models of metal machines were found was either their association with a welder or proximity to trading centres where welding was possible. As with the NARO reproduced model, welders played a critical role in the making process. Fabricating agricultural tools was not their main line of work; they mainly made frames for windows and doors, metal gates, metal windows and metal doors. Although the quality of some of the machines was not comparable to that of the NARO device, welders were an important source for the machine for some farmers. Even with the evident poor workmanship, the role of the welder in fabricating forage choppers points to a crucial group of resource persons that technology developers can utilize to increase farmers' access to the machine and offer after sale services. This draws attention to the way designers define spaces to be occupied by participation in the design process. Broadening engineers' spaces of participation to include a community resource in the socio-technical system would benefit both technology users and designers.

What then?

If (as shown) users are not merely passive recipients of technology but actively involved in the process of making and re-making tools and machines then it follows that there should be some strategies for tapping into this innovativeness as part of an organized feedback process. Designing feedback mechanisms is an important aspect of the iterative design process. Feedback not only shapes the tool, but also the organizational context of technology for designers and users. Feedback from users is also important, because they experience problems designers have not fully conceptualized. A social learning perspective would be an important addition to the iterative design. This approach recognizes that users engaging with a new technology also contribute to redefining it, through shaping its use and social significance, even when nothing substantial happens to the tool or machine itself. Picking up on this social learning process is an important way of instructing designers about the unanticipated potential or drawbacks to their design.

Overall conclusion:

This paper has described what needs to be done for research centres to have an inclusive approach to generating technologies rather than providing clear-cut solutions. This has been illustrated with the introduction of the forage chopper in Uganda. It has been argued that instead of using the highly procedural approaches of either focusing at the lower end of the connection that emphasizes the role of users or on the top-end that emphasizes collaboration between various partners, a case-by-case approach that includes the basic lessons from STS and anthropological accounts is needed. The case has shown that there is a need to establish a functional connection between the production of knowledge and technology in research/engineering centres and the production of knowledge and technology at the field level.

The making and remaking process of the forage chopper points to two aspects of the design process: the participation of different actors and a feedback process. These findings point to the desirability and feasibility of increasing users' participation in the design process. The role of users in the design process and the dynamic inter-dependence of design and use now needs to receive more attention as a means of developing workable technologies. The current mode of participation is in such a way that there is an environment (the engineering workshop) where the physical design takes place, where the design takes shape, where engineers and technicians interact with the technical objects. It creates the framework that helps designers to define their responsibility in socio-technical networks. But it also excludes some other actors from the design process. This presents two challenges to users' participation: the public normally lacks knowledge of decisions made in the design process, and there is limited opportunity for the voices of users to be heard when decisions about design are made.

Considering the social demands in engineering, there is need to map out strategies for designers (engineers) to open up the technology design space, and to create opportunities for users to participate in the design process itself. Users need to be given an active role in the design process by building their capacity to demand technology developers to address actual needs. Emphasis here should be on collective action by building "client groups" that can function to commission and evaluate designs. Key in achieving this is the need for designers to review how they perceive the actual users of the technologies. Design efforts that target specific users are very often framed in a way that extracts them from their work environment, creating wrong ideas about who the actual users are, and resulting in ineffective policy implementation. Sociological analyses must be built within the design process as an approach to help designers reconfigure their relations with users. This will require engineers to move beyond the technology itself and become "engineers of the social". This means a new role for technology developers, moving beyond conventional wisdom in terms of supplying technologies towards a greater emphasis on "engineering" (or managing) uptake/use based on careful analysis of target group social dynamics and equally careful analysis of the material environment.

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