ABSTRACT
In this paper, we outline a theoretical framework for understanding the role of technologies in interactions between scientists and farmers. Technologies are important mediators of relationships in modern, industrial agriculture. Scientists have attempted to make agricultural science more accessible for farmers through decision support systems (DSSs). However, the limited uptake by farmers of this form of technology has led to critical reflection on the development and implementation of agricultural DSSs. The shift towards participatory research and development approaches recognises the benefits of fostering collaborative and mutually beneficial relationships between scientists and practice communities. However, a more detailed analysis of the interaction between the multiple actors involved in participatory DSS development is required to identify principles to improve this process. We have developed a theoretical framework to analyse participatory DSS development in the Australian sugar industry. Our framework is based on three concepts from science and technology studies: interpretative flexibility, technological frames and boundary objects. We illustrate this framework with a case study of an irrigation scheduling DSS.

1 INTRODUCTION
Issues such as declining profitability of agriculture, climate variability and increasing concerns over the environmental impacts of farming pose complex challenges for farm management. The development of decision support systems (DSSs) to improve farm management illustrates the way in which technologies can act as intermediaries that facilitate interaction between scientists and farmers. DSSs are seen as a means of making agricultural science more accessible and useful for guiding farm management (McCowan, 2002). DSSs are software applications based on simulation or other quantitative analysis. Participatory DSS development involves local actors and researchers cooperating as active co-experimenters engaged in joint learning (Ridley, 2004). Participatory DSS development integrates researchers’, developers’ and users’ perspectives to clarify objectives and foster co-learning (Walker, 2002). We examine the social context and processes of participatory DSS development using a theoretical framework based on three concepts from science and technology studies: interpretative flexibility, technological frames and boundary objects. The framework also allows for clearer definition of potential outcomes of participatory DSS development. We illustrate the framework through a case study of an irrigation scheduling DSS.

1.1 THEORETICAL FRAMEWORK
Science and technology studies demonstrate that ‘scientific knowledge is not the passive product of nature but an actively negotiated, social product of human inquiry’ (Cozzens and Woodhouse, 1995:534) and that technology is ‘a social product, patterned by the
conditions of its creation and use’ (Williams and Edge, 1996:866). Interpretative flexibility means that any object can mean different things to different people, depending on the contextual factors (Hess, 1997). When applied to DSSs, the concept of interpretative flexibility emphasises that a DSS will mean different things to the various people involved its development. Technological frames are the assumptions, beliefs and expectations that groups of people hold about a specific technology, which in turn influence the design and use of that technology:

Technological frames provide the goals, the ideas, and the tools needed for action. They guide thinking and interaction. A technological frame offers both the central problems and the related strategies for solving them. (Bijker 1995:191-192)

The concept of boundary objects was introduced by Star and Griesemer (1989) in their study of the early years of the Museum of Vertebrate Zoology at the University of California, Berkeley. They define boundary objects as:

...objects which are plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. (Star and Griesemer, 1989:393)

Examples of boundary objects include maps, diagrams, computer models and forecasts (Cash, 2001). The concepts of interpretative flexibility, technological frames and boundary objects can be combined in a theoretical framework (Figure 1) that clarifies the process of participatory DSS development, and identifies three potential outcomes of this process. The overall structure of Figure 1 was inspired by Pahl-Wostl and Hare’s (2004:194) model of social learning.

Figure 1. Theoretical framework of the context, processes and outcomes of participatory DSS development.
Any technology, including a DSS, is conditioned by its external social, cultural, political, economic and biophysical context. The contextual factors that can influence participatory DSS development include macro-level economic factors, such as world markets, through to micro-level social and cultural factors, such as farming traditions and individuals’ educational and generational backgrounds and attitudes towards risk (Doorman, 1991).

The outer circle in the framework indicates that the concepts of interpretative flexibility and technological frames can help to understand the social context of participatory DSS development. Technological frames may be held in common or differently by different people. Orlikowski and Gash (1994:180) refer to the practice of holding similar technological frames as congruence, namely ‘the alignment of frames on key elements or categories’. Incongruence in technological frames occurs when different people hold differing expectations or assumptions about some important aspects of the technology. Orlikowski and Gash (1994) argue that incongruence in technological frames can create difficulties for the application of a technology, since it can lead to conflicts over the use and value of the technology. Therefore, gaining increasingly congruent technological frames is a key objective of participatory DSS development.

The inner circle in the framework focuses on the processes involved in participatory DSS development. By mediating differences and providing a common point of reference, boundary objects facilitate cooperation between different groups of people. Cash (2001) explored the way in which scientific models can act as boundary objects in agricultural extension, highlighting the potential for different kinds of models (including cropping, hydro-geologic and economic models) to serve as boundary objects:

...models themselves can act as boundary objects, dependent on both the participation of farmers to get inputs that reflect reality and outputs that are useful, as well as on scientists who incorporate basic research on the systems under study and the technical capacity to guide the endeavor. (Cash, 2001:441)

The use of boundary objects can facilitate collaboration between diverse groups of people, which in turn can provide mutually beneficial outcomes.

During participatory DSS development, a DSS may act as a boundary object, creating a temporary bridge that promotes dialogue between the various people involved in its development, while remaining flexible enough to be used by the different parties for their own purposes (Cash, 2001). Through the negotiation, cooperation and co-learning that the DSS-as-boundary object can facilitate, the parties involved in participatory DSS development may arrive at an increasingly shared understanding of the problem, which works towards increasingly congruent technological frames.

The framework also highlights three potential outcomes of participatory DSS development. One outcome may be acceptance by potential users of the value of ongoing use of the DSS. Further cycles of negotiation and co-learning may be necessary to modify the DSS for this routine role (e.g. through making the software more user-friendly). Once the DSS is ready for routine use, emphasis shifts from negotiation and co-learning to adoption of the DSS by farmers and their advisors. This leads to Outcome 1, whereby a DSS may be able to influence farmers’ management decisions through its continued role in problem solving. Once developed and proven in this role, the DSS can be distributed through standard diffusion and extension programs.

However, the cycles of negotiation and co-learning that occur through participatory DSS development may lead to a better understanding of the problem and its context. This may allow for simplification of the problem within the specific management and/or biophysical context and result in the discovery of a new and widely applicable
management practice with ongoing relevance, which can be applied without ongoing use of the DSS (Outcome 2). This results in the development of a management recommendation, which can be routinely used by farmers and their advisors.

The framework also recognises that through the DSS development process, the parties involved may find that there is no reason to change current practice (Outcome 3). This third outcome may occur because participatory DSS development has led to a better understanding of the problem and acceptance that there is no need or opportunity for changes to the current management practice. It may also occur if the parties involved believe that the DSS will not provide a sufficient advantage necessary to justify its use.

1.2 CASE STUDY OF AN AGRICULTURAL DSS

Like other agricultural industries in Australia, deregulation, restructuring and the need for international competitiveness create an ongoing pressure for improvements in productivity and efficiency within the Australian sugar industry (Hildebrand, 2002). Investment in technologies is one of the ways that the sugar industry has responded to this pressure. This section presents a case study of the development of an irrigation scheduling DSS, which is drawn from a project examining technology development and adoption in the Australian sugar industry (Jakku et al., 2007). Semi-structured, in-depth interviews were carried out with 32 of the key people involved in the development of three technologies within the sugar industry. Interviewees included growers, extension officers and scientists across four sugar-growing regions in eastern Australia. This section focuses on the experiences of the nine interviewees who were involved in the development of an irrigation scheduling DSS in the Bundaberg region.

A DSS called WaterSense, developed initially as part of the Rural Water Use Efficiency Initiative, is designed to enable sugarcane growers to assess when to use their limited water. The scientists developing the tool worked closely with a small group of growers and extension officers in Bundaberg. This collaboration has been essential for the further development of WaterSense. The interactions through the industry group allowed the scientists, growers and extension officers to explore their different perspectives on irrigation and provided an opportunity to express their technological frames and gain insights into others’ frames:

The right ingredients to have in these sort of projects is respect from the different parties involved so the researcher has a respect that the issues at the grower level or extension level can feed back into the research project and also there’s got to be a respect from the grower and the extension officer to say that the research findings are relevant to them as well. ...when you respect those parts you have a successful collaborative-type project and I think that project had those ingredients. (Extension Officer)

The participatory development of WaterSense facilitated a common learning experience, the beginning of making the technological frames more congruent. The collaboration has created strong ownership of WaterSense among the group members:

...they were committed, they took ownership, and they felt that we valued their input. And I believe also that for me, that these people were all...really contributing, and helping to progress the technology. (Scientist)

...the difference was that the growers were being asked to tell the scientists what they didn’t know, and that brought growers onboard. What...the growers thought the scientists didn’t know, I suppose is a better way of putting it. They were having their point of view listened to. (Extension Officer)
...it comes back to the confidence side of things; there was growers involved with it [WaterSense]. Whereas...sometimes, some ideas are put up and growers may not have had much input into what they wanted, what they expected out of it. I feel we got a fair bit of input into what we expected of it, and yeah, I like it, it’s good. (Grower)

Through its development, WaterSense acted as a boundary object, as the scientists, growers and extension officers explored the assumptions of the tool, allowing all participants to gain a better understanding of irrigation and the consequences of different irrigation strategies. As one of the extension officers explained:

...it was bridging that gap between what was seen to be pretty good science, but making sure that it was paddock useable. [WaterSense]...could’ve been developed in an office in Townsville and it could’ve been spat out on a disk, and I don’t think anybody would’ve used it. ...the process of developing it and taking the science to the people and the people to the science and bringing the two together so as at the end of the day, something was useful to the grower at his level rather than the scientist at his level, has been the real deal.

Despite the references to collaboration among the group members, there is still evidence of a hierarchy between the scientists, extension officers and growers, as seen in the comments comparing the grower 'level' and the scientist 'level'. Furthermore, the grower’s comment regarding confidence in WaterSense underlines the importance of building trust among the scientists, growers and extension officers. These comments highlight the challenges of participatory DSS development. However, a full discussion of these issues is beyond the scope of this paper.

There has been interest in delivering WaterSense over the internet, which suggests that WaterSense could reach Outcome 1 of the framework, whereby the complexity of the irrigation scheduling problem that WaterSense addresses means that it may be routinely used by some growers. In doing so, WaterSense may influence growers’ irrigation management decisions by calculating optimum scheduling of irrigation in the context of limited water supply and uncertain rainfall.

2 DISCUSSION

We have provided a theoretical framework for analysing the social context and processes that shape participatory DSS development. The concepts of interpretative flexibility and technological frames reinforce the importance of acknowledging the different perspectives held by people involved in participatory DSS development and then working towards a shared understanding. The framework also illustrates the way in which participatory DSS development can break down the barriers between the developers and potential users of DSSs. When used as a boundary object, a DSS encourages co-learning between those involved in its development. The idea that a DSS can act as a boundary object and encourage dialogue and collaboration between industry participants and scientists resonates with calls for a shift in thinking about the role of agricultural DSSs made previously (e.g. Leeuwis, 1993; Stone and Hochman, 2004). Thus, appreciating the way in which a DSS can act as a boundary object recognises how cooperation and co-learning among those involved in DSS development can occur, despite the fact that these people can hold diverse perceptions of a DSS or the issue it is designed to address.

Our framework also recognises that a DSS may become redundant once it has fulfilled its function as a tool for co-learning. The use of a DSS may cease once it leads to a clearer understanding of the problem by all, and a subsequent management recommendation is developed based on this understanding. Successful DSS development should be viewed
as a participatory process leading to practice change, which in turn results in improved farm management, irrespective of whether or not this involves ongoing DSS use.

3 CONCLUSION

Our theoretical framework characterises participatory DSS development as a co-learning process between actors with complementary contributions. The framework clarifies three potential outcomes of participatory DSS development and suggests that successful DSS development should be defined in terms of practice change, rather than solely being based on the ongoing use of a DSS. Our framework demonstrates the way in which science and technology studies can facilitate reflection on the core principles for improving the participatory development of DSSs that can help farmers deal with the complexity of farm management. We hope that our framework provides scientists and others involved in the development of agricultural technologies with new conceptual tools to reflect on their practice and in doing so, contributes to enabling more effective participatory technology development processes.

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5 REFERENCES


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