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ON-FARM INNOVATION IN THE AUSTRALIAN WOOL INDUSTRY: A SENSEMAKING PERSPECTIVE

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SUMMARY

In agricultural innovation, the success of widely used technologies is often assumed to have been inevitable. Conversely, the blame for the failure of new technologies that researchers, policy makers and extensionists consider superior to existing solutions is often placed on farmers. However, these assumptions can be challenged by taking a social-constructivist view of on-farm innovation to examine how and why farmers made sense of new technologies and how this sensemaking shaped their use of these technologies over time. The present study took such an approach in its analysis of Australian woolgrowers' adoption, abandonment, implementation and use of new wool-testing technologies that highlighted the social and dynamic nature of innovation on-farm. On-farm innovation in this case was an evolving, dynamic process that changed over time as woolgrowers made sense of new technologies. The primary message to agricultural innovation researchers, technology developers, policy makers and extensionists is that successful on-farm innovation requires the active, ongoing engagement of industry participants. In order to engage industry participants in the innovation process, sensemakers' personal identity frames and social context, and how these interpretation frameworks relate to the new technology need to be understood.

INTRODUCTION

For many years, technology has been considered a silver bullet that can solve the profitability, productivity and sustainability problems that many agricultural industries face. However, new agricultural technologies often fail to meet researchers', practitioners' and end-users' expectations. The gap between what industry participants expected of new agricultural technologies and what is delivered can be seen in the variable levels of technology use and industry impact (e.g. Barnett and Sneddon, 2006a; 2006b; Carletto, de Janvry and Sadoulet, 1996; Moser and Barrett, 2003; Neill and Lee, 2001). In agricultural innovation, technologies that are widely accepted and used are often assumed to be what Pinch and Bijker (1987) term *technologically sweet*, which means they were an advanced piece of science and engineering that resolved the problem which they were designed to address and that their success was inevitable. Conversely, the blame for the rejection, abandonment or failure to adopt and implement new technologies that researchers, policy makers and extensionists consider superior to existing solutions is often placed on farmers

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(Guerin and Guerin, 1994; Ruttan, 1996). However, is there evidence to support these assumptions? Is the success of one agricultural technology inevitable because it is technologically sweet and the failure of another the fault of end users who failed to see its superiority, or is agricultural innovation a more complex phenomenon than these basic assumptions suggest?

In contrast to the dominant determinist perspective of agricultural innovation, technologies have been viewed as socially constructed variables, with designs manifested in different ways to suit different participants (Bijker, 1999). New technologies can be considered 'equivocal', as they '*require ongoing structuring and sensemaking if they are to be managed*' (Weick, 1990: p. 2). Innovation management and organizational behaviour researchers now recognize that understanding how people make sense of new technologies is an important issue (e.g. Choo and Johnston, 2004; Griffith, 1999; Seligman, 2000). However, little has been said about the process through which participants make sense of new technologies and how sensemaking shapes the use of technologies on-farm.

The present study investigated innovation in the Australian wool industry, which, despite a long history of innovation-based development (Australian Bureau of Statistics, 2002), has been criticized for poor productivity gains since the 1970s (Productivity Commission, 2005). Australian wool industry commentators argue that investment in innovation initiatives has not prevented a decline in wool production and enterprise productivity as woolgrowers have a low level of technology adoption compared with other Australian rural industries (Woolmark Business Intelligence Group, 2004; Wool Industry Future Directions Task Force, 1999). However, few studies have examined how new technologies are adopted, implemented or used by Australian woolgrowers and there is a need to understand more about this aspect of the innovation process and how it can be better managed to improve industry outcomes. Therefore, the present study examined how Australian woolgrowers made sense of new technologies and how this sensemaking shaped their use of these technologies on-farm.

THEORETICAL PERSPECTIVE

It is important to explain what is meant by the term *sensemaking*. Sensemaking has been described as 'a cognitive and behavioural response to ambiguous and uncertain situations that interrupt the ongoing flow of events' (Gioia and Chittipeddi, 1991) and is an ongoing process of forming anticipations and assumptions and the subsequent interpretation of experiences that deviate from those anticipations and assumptions (Louis, 1980). *Sense* in this context refers to the meaning ascribed to an event and *making* is the activity of creation or construction (Weick, 1995). Sensemaking frameworks reflect sensemakers' habits and beliefs about *what is* and *what ought to be* (Weick, 1995). Sensemaking occurs at all levels of a social system, from the individual to the industry or even cultural level (Beyer, 1981; Porac, 2002; Weick, 1995; Wiley, 1988).

Weick (1979) argues that to understand sensemaking is to address the question of what provokes cognition in social settings. New technologies can trigger sensemaking because they can be uncertain and complex and have multiple possible or plausible interpretations (Griffith 1999). Indeed, Orlikowski and Gash (1994: p. 175) argued that, to '*interact with technology, people have to make sense of it; and in this sensemaking process, they develop particular assumptions, expectations and knowledge of the technology, which then serve to shape subsequent actions towards it*'. Although Weick (1995) associated sensemaking with other explanatory processes, he argued sensemaking has seven properties that make the process of theorizing and construction unique, namely:

1. *Sensemaking is grounded in identity construction*: Identity construction is the interplay between how people see themselves, how they see a situation and their perceptions of how others view them. Sensemakers view a technology in relation to their own identity construction in terms of their assumptions about its functions and use and expectations of its performance, their experience and knowledge of existing technologies and practices and their current projects and goals (Orlikowski and Gash, 1994; Weick, 1995). For example, 'progressive' farmers are highly regarded by the scientific community, elevating their social status in the farming community (Vanclay, 1994).
2. *Sensemaking is retrospective*: A crucial element of sensemaking is the notion that, although situations are progressively clarified, clarification often works in reverse (Weick, 1995). For example, if a person's attitudes towards a new technology are influenced by a set of norms and beliefs, their experience with the technology may change these beliefs and their frames may evolve to exclude some original perceptions (Rice and Contractor, 1990).
3. *Sensemaking is enactive of sensible environments*: Sensemakers construct their reality by taking action and the environment that they create is sensible to them because they label their reality with meaning (Weick, 1995). In enacting their environment, people set apart or 'bracket' events from ongoing experience flows in order to make sense of them. The act of bracketing is based on the subjective norms and beliefs of the sensemaker (Weick, 1995). For example, Coughenour (2003) found new social networks were enacted by participants engaged in the construction of new no-tillage cropping technologies.
4. *Sensemaking is social:* Sensemaking is social: The social nature of sensemaking involves how people view themselves and technologies in relation to their peers, their colleagues, their social groups, the industry to which they belong and the norms of that industry group (Biemans 1992; de Souza and Busch 1998; Fincham *et al* 1995; Fleck 1994; Preece 1989; Tanaka, Juska and Busch 1999; Weick 1995). For instance, Coughenour (2003: p. 285) found the construction and reconstruction of conservation technologies was a 'process and product of new networking'.
5. *Sensemaking is ongoing*: Sensemaking 'neither starts fresh nor stops cleanly' (Weick, 1995: p. 49) as people act, makes sense of their actions and then act again, guided by the sense they have already made. Swanson (1994) suggested the adaptation of a new technology is an ongoing, evolutionary sensemaking act. Indeed, Coughenour and Chamala (2000) found the 'adaptive modification' of conservation technologies continued almost indefinitely.

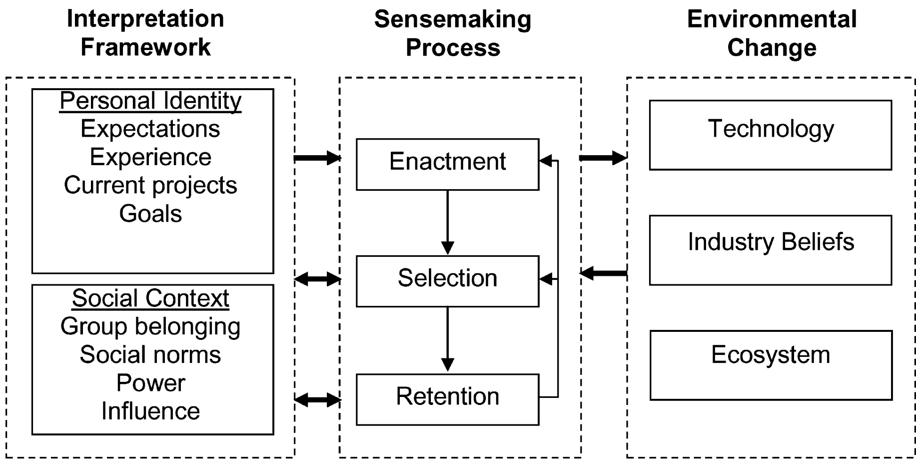

Figure 1. Agricultural innovation sensemaking analytical framework.

6. *Sensemaking is focused on and by extracted cues*: Cue extraction is the process of 'noticing' and extracting what is salient and useful for mentally representing stimuli (Starbuck and Milliken, 1988).
7. *Sensemaking is driven by plausibility rather than accuracy:* Sensemaking involves the embellishment of a point of reference or an extracted cue (Weick, 1995). People give meanings to situations that are 'good enough' to enable them to undertake effective actions (Fiske and Taylor, 1991: p. 182). As Lindner (1987: p. 149) pointed out, farmers operate in their own self-interest, which involves their values and preferences and is not a measurable, objective 'truth'.

In this study, the adoption, abandonment, implementation and use of new agricultural technology was conceptualized as an evolutionary, socio-cognitive sensemaking process in which farmers noticed, bracketed and selected salient cues to create a plausible story about the technology that guided their actions toward that technology on-farm. This conceptualization of sensemaking in an agricultural innovation context is shown in Figure 1, which guided the collection and analysis of data in this study.

In this model, the interpretation framework of the sensemaker has two aspects (personal identity and social context) that are ongoing, interrelated constructions. Based on other scholars' contributions, the following aspects of the proposed interpretation framework were considered relevant to the present study:

- *Personal identity:* Sensemakers need to establish and maintain a self-identity (Weick, 1995). Consequently, sensemakers view a technology in relation to their own identity construction in terms of their assumptions about the functions and use of the technology, expectations of the performance of the technology, experience and knowledge of existing technologies and practices and current projects and goals

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(Agarwal and Prasad, 1999; Orlikowski and Gash, 1994; Sproull and Hofmeister, 1986; Weick, 1995).

- *Social contex:* Represents the social nature of sensemaking that binds people to actions that need social justification, affecting the saliency of cues they extract from events, and providing the norms and expectations against which extracted cues are measured (Weick 1995).

In this study it is proposed that farmers make sense of changes in their environmental, such as the introduction of a new technology through an evolutionary, sensemaking process. As technological change occurs, farmers notice and bracket cues and select salient cues to create a plausible story about the new technology that guides further actions towards it.

MATERIALS AND METHODS

Rogers (2003) argued the focus of innovation research should be on the dynamic nature of the innovation process; emphasizing the 'how' and 'why' of what occurs. The case study method allows researchers to examine these 'how' and 'why' issues in their natural setting (Yin, 1994). Consequently, the present study used a multiple case study approach.

The innovation examined was Additional Measurements (AM), a technology introduced to the Australian wool industry in 1986. Additional Measurements involved the pre-sale testing of individual wool lots for staple strength (SS) and staple length (SL), which has evolved into an important technological and marketing system. However, AM's history has been marked by highly variable adoption and use, technological failures and successes and conflict between Australian wool industry participants (Sommerville, 2002)

Six commercial Western Australian wool production enterprises were purposely selected as cases from the wool auction database[1] to provide sufficient data without constraining data analysis (Eisenhardt and Tabrizi, 1995). A cluster analysis was used to find groups of homogeneous commercial wool production enterprises in terms of enterprise size and the adoption and use of AM, so similar cases could be selected from within the clusters obtained (i.e. literal replication) and contrasting cases could be selected from across the clusters (i.e. theoretical replication) (Yin, 1994). Ward's clustering technique was used as such clusters tend to be more coherent than other approaches (Hair *et al.*, 1998). As there was a relatively large increase in the agglomeration coefficient when combining four to three clusters, a four-cluster solution was used to select the six enterprises, which were selected at random from the four clusters. A letter was sent to the farm families operating these enterprises requesting their consent to participation and each agreed. The key characteristics of the six farms are summarized in Table 1, while Figure 2 shows the proportion of wool offered at auction with AM by the six farms from 1988 to 2003.

[1] The Australian wool auction database records the details of every wool sale lot offered at auction in Australia.

Table 1. Key characteristics of the cases studied.

Cluster	Name[†]	Farm structure and interviewees	Size	Income	Av. kg wool (p.a)	Year AM adopted	Av.% wool with AM (p.a)
1	Dorset farm	2nd generation family farm, inherited 1999 Farmer, spouse, father, broker	1500 ha 3200 sheep	60% sheep and cattle, 40% crops	22 458	1989	73
1	Saxon farm	3rd generation family farm, inherited 1994 Farmer, spouse, broker	1200 ha 4000 sheep	45% wool, 22% sheep meat, 33% crops, >1% ram stud	30 967	1990	35
2	Polwarth farm	2nd generation family farm, inherited 1996 Farmer, spouse, broker	800 ha 1700 sheep	30% wool, 30% sheep meat, 40% crops	25 564	1990	58
3	Peppin farm	4th generation family farm, acquired 1990 Owner, farm manager, broker	3500 ha 10000 sheep	33% wool, 14% sheep meat, 50% crops	42 457	1988	73
3	Coriedale farm	5th generation family farm Farmer, son, broker	7000 ha 8000 sheep	40% ram stud, 20% wool, 20% sheep meat, 20% crop	43 111	1989	49
4	Romney farm	2nd generation family farm, inherited 1980 Farmer, broker	4000 ha 9000 sheep	40% wool, 30% sheep meat, 30% crops, >1% ram stud	41618	1988	61

[†]Not the actual name of the enterprise. The real names of the farm and the farming family are disguised to maintain confidentiality.

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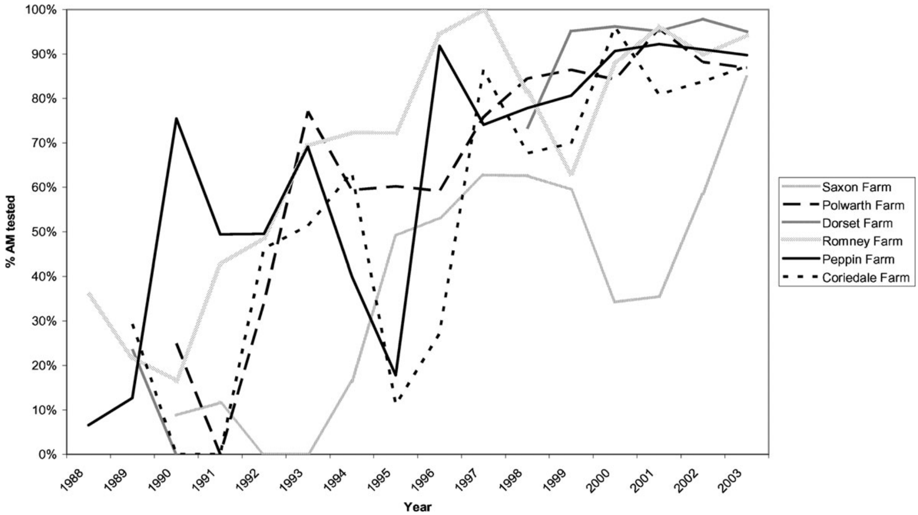

Figure 2. Wool with AM offered by the six case study farms, 1988–2003.

A case study protocol was prepared and used to guide the data collection process. Data were collected through interviews with woolgrowers and their brokers and from physical and documentary sources. Typically, four interviews were conducted within each farm business, each lasting, on average, 74 minutes. The case study interview data was combined with wool auction data for each farm business to clarify and triangulate responses. Potential researcher bias was addressed through consistent and rigorous accuracy-checking of data by participants. To ensure interview data were representative of interviewees' responses, transcripts of the interviews were drafted and returned to participants for accuracy-checking prior to analysis.

A database was created in the QSR N6 qualitative data analysis software and a coding scheme was developed to organize and analyse the data. Initial codes were adopted from the seven properties of sensemaking described earlier. In order to understand how AM was enacted on-farm, a logical chain of evidence, based on the sensemaking properties, was developed through a process of within case and cross-case analyses (Eisenhardt, 1989).

In the following section, the story of how and why AM was enacted on the six farms is recounted in relation to three phases of on-farm innovation that were encountered, namely:

1. The adoption of AM on-farm
2. The implementation of AM on-farm (year of adoption to 1994)
3. The use of AM on-farm (1995–2003)

Phase 1 related to the adoption of AM on-farm. In phase 1 of the case analysis, the enactment of AM by the six farms was examined in terms of the decision to adopt AM and the first use of these testing technologies. Phase 2 of the case analysis examined the implementation of AM on-farm by the six farms. In this phase, the enactment of AM on-farm was examined from the period directly after the adoption of AM to 1994, when price premiums for wool offered at auction with AM emerged in the market. Phase 3 of the enactment of AM and CC on-farm examined the use of AM on the six farms from 1995 to 2003.

CASE STUDY FINDINGS

1. The adoption of AM on-farm

The six farms tested 7–36% of their clip when they adopted AM. The majority adopted AM to test a small proportion of relatively high quality Merino fleece wool and its adoption was strongly influenced by interactions between the woolgrowers and their wool selling brokers. Cues extracted from interactions with brokers about the adoption of AM were interpreted by woolgrowers through their personal identity frames and social context in terms of social influence, the normative beliefs and behaviour of their industry group, their experience and knowledge of objective wool measurements and their existing farming practices and goals.

In the late 1980s, the lack of support for AM among wool buyers translated into a lack of demand for wool lots offered with AM. The lack of demand for AM at auction constrained the adoption of AM among the woolgrowers interviewed, as they were unable to extract meaningful price cues for AM. The brokers interviewed advised their clients to reject AM or to adopt the tests with great caution in order to avoid unnecessary discounts.

The belief shared by the brokers interviewed was that Western Australian (WA) wool was relatively tender and that AM would highlight a discount feature that could be avoided if woolgrowers continued to use subjective appraisal. The influence of brokers' beliefs on AM adoption behaviour was reflected in their selection of relatively sound sale lots for testing. With the exception of the Saxon farm, the farms initially tested sale lots with a relatively high average diameter. The woolgrowers and their brokers assumed Merino fleece wool with relatively high fibre diameter would be less likely to test tender than the finer portions of their clip.

The Polwarth farm family was initially told about AM by their broker, who advised them to approach the tests with care. They adopted AM in 1990. As there was little evidence of price premiums for sale lots with AM in the market, they tested only 25% of their clip on their broker's advice. According to Mr Polwarth, their broker was reluctant for them to test their whole clip out of a concern that relatively tender sale lots would be heavily discounted. However, there was no evidence that the price received for Polwarth sale lots with AM in 1990 attracted additional discounts.

The Dorset farm family was persuaded to adopt AM in 1989 by their broker, who advised them it was 'inevitable' growers would test for staple strength and length. Despite endorsing AM, their broker advised them to test only a small proportion (23%) of their clip and to test only sound Merino fleece wool. Mr and Mrs Dorset did not test sale lots with relatively fine fibre diameter (under 20 μ) or sale lots with

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vegetable matter (VM)[2] content of over 1.2 per cent as these lots were subject to discounts for tenderness and low yield. The adoption of AM for relatively high quality sale lots was reflected in a higher average price for sale lots with AM than for untested lots.

Peppin and Romney Farm brokers advised their clients to reject AM. The Romneys ignored their broker's advice and tested 36% of their clip in 1988. Mr Romney felt they would be able to use AM to objectively determine that their clip was not tender and avoid unnecessary discounts. The Romneys did not test relatively fine portions of their clip (under 21 μ) or sale lots with VM content of over 0.9% as those lots were subject to discounts for tenderness and low yield. The price difference between similar quality sale lots offered with and without AM confirmed Mr Romney's beliefs that their clip had been discounted in the past for tenderness on the basis of inaccurate subjective appraisal.

As already noted, the Peppins' broker advised them to reject AM as he believed the tests had not been properly validated. While the Peppins adopted AM in 1988, they tested only seven% of their clip. Mr Peppin offered Merino fleece sale lots with AM with relatively high fibre diameter and low value compared with untested sale lots. These sale lots were offered with AM to reduce the risk of highlighting the discount features of premium Merino fleece lines.

There was little evidence of price premiums for sale lots with AM or discounts for sale lots without AM until 1994 (Lax, Jackson and Dryden, 1995). The lack of premium and discount data for AM was confirmed by the Dorsets, who recollected they were not persuaded to adopt AM by evidence of price premiums. However, the Saxons described their decision to adopt AM in 1990 as being influenced by observable price premiums, specifically for Merino pieces[3] with long staples. In contrast to the other farms, when the Saxons adopted AM in 1990 they tested the majority of their relatively low quality Merino pieces and other wool types, but did not test Merino fleece wool.

The fixed price premium for AM wool purchased under the Wool Reserve Price Scheme (WRPS)[4] influenced the Polwarths' and Dorsets' decision to adopt AM. When the Dorsets adopted AM in 1989, they sold all of their tested wool under the WRPS. The Polwarths offered 75% of their sale lots with AM under the WRPS in 1989. Although the Peppin and Romney farms did not sell wool with AM under the WRPS when they adopted the tests, both farms tested sale lots under the scheme in subsequent years. However, neither the Peppins nor the Romneys recollected their adoption and implementation of AM as being influenced by the fixed price premium under the WRPS. None of the sale lots sold under the WRPS from the Coriedale and Saxon farms was subject to AM. Mr Coriedale and Mr Saxon believed the fixed price premium for tested wool would have been swallowed up by the cost of testing.

[2]Vegetable contaminants such as burrs, twigs and grasses in greasy wool.
[3]Wool removed from the sheep at shearing which is not part of the main fleece.
[4]The Wool Reserve Price Scheme set a floor price for wool for the season.

Mr Coriedale described the adoption of AM in 1989 as a means of achieving their enterprise goal to be as objective as possible in the measurement of the performance of their wool enterprise and ram stud. The Coriedales adopted AM on Merino fleece and weaners[5] wool lots across a relatively broad range of fibre diameter (19.4–21.5 μ). However, they avoided testing sale lots with relatively high VM content as those lots were subject to discounts for low yield.

The woolgrowers interviewed who operated ram studs, namely the Coriedales, Saxons and Romneys, shared a belief that the performance and reputation of their ram stud could be enhanced with more objective measurements of wool attributes. This shared belief was articulated through the inclusion of staple strength in their ram breeding index over time as they believed ram buyers would eventually demand AM data.

2. The implementation of AM on-farm

Each of the farm families interviewed had adopted AM by 1991. However, it was evident from the highly variable use of AM on the farms, as can be seen in Figure 2, that the implementation of AM was a dynamic process. The farms tested between 7 and 53% of their clip during this phase. The majority continued to test Merino fleece lines and also began to test weaner wool and pieces. The implementation of AM across different types of wool was reflected in the decrease in the average diameter of wool with AM on the Polwarth, Peppin, Coriedale and Romney farms. The increase in types of wool offered with AM was also reflected in the increase in the average VM content of wool with AM on the Coriedale, Romney and Peppin farms. However, the six farms continued to test relatively high quality sale lots in terms of wool type, VM content and SS during the implementation phase.

Although four of the six brokers interviewed recommended that their clients adopt AM, their approach towards the implementation of AM remained cautious as they were concerned the wool market would be distorted by comprehensive testing. The brokers' cautious approach towards AM influenced the type, proportion and quality of wool tested on the case study farms. The brokers interviewed continued to advise their clients not to test tender wool in order to avoid additional discounts. According to the Coriedales' broker, prior to 1994 the discounting of tender wool offered with AM was a blunt tool that was best avoided by relying on subjective appraisal.

During the AM implementation phase, the Polwarths avoided testing any wool that was subjectively appraised as tender. In contrast, the Romneys began to test relatively tender wool in 1988, which reflected their goal to prove that their clip was sound. The Saxons were strongly advised by their broker not to test the tender portion of their clip. However, the majority of the Saxon farm clip was relatively tender (under 35 Newtons per kilotex[6]) as a result of increased stocking rates. Despite being advised against testing tender wool by their broker, Mr Saxon explained much of their tender wool was tested as a result of poor in-shed

[5] Fleeces from sheep over six months old shorn for the first time.

[6] Maximum force required to break the staple. Kilotex – unit of measurement expressing thickness in grams per meter.

classing as they found it difficult to accurately class wool according to staple strength.

The woolgrowers interviewed expanded their use of AM from testing mainly Merino fleece to Merino weaner wool and pieces during the AM implementation phase. The Coriedales began to test Merino pieces in 1992 in response to pressure from other woolgrowers and price signals. The Peppin, Romney and Saxon farms offered Merino pieces sale lots with AM by 1995. The Peppins and the Saxons attributed the testing of different types of wool during this phase to broker influence and positive market signals for sale lots with AM.

Merino weaner wool was tested on the Peppin, Romney and Saxon farms for the first time during this phase. These woolgrowers attributed the decision to test weaners' wool to broker influence and their flock structure and time of shearing. For example, the Saxons, who tested their Merino weaner wool for the first time in 1995, explained that because of the time of shearing on their farm, much of their Merino weaner wool tested short and was discounted heavily. Therefore, they abandoned testing Merino weaner wool after 1995.

The Polwarths did not expand their use of AM across different wool types during this phase. They avoided testing wool types other than high value Merino fleece in order to avoid what they perceived to be heavy discounts for lower quality wool with AM. On the advice of their broker the Polwarths continued to offer only Merino fleece with AM at auction until 1997. In 1997 the Polwarths' new broker advised them to test all wool types. The new broker argued the more testing that was undertaken on the Polwarth clip, the less the chance the wool would be subject to unnecessary discounts as a result of inaccurate, subjective appraisal.

In 1991 the price of wool collapsed and the WRPS was abandoned, along with the fixed price premium for sale lots purchased under the scheme with AM. On the Polwarth, Coriedale, Saxon and Dorset farms, AM were temporarily abandoned (see Figure 2) as these woolgrowers strove to cut what was perceived to be non-essential costs. However, the Peppins and the Romneys continued to offer lots with AM throughout this phase. Forty-nine per cent of the Peppins' clip and 43% of the Romneys' clip were offered with AM in 1991. They continued to offer wool with AM to avoid additional discounts that would have further reduced the prices received in a tight market.

3. AM use on-farm

As Australian woolgrowers began to recover from the collapse of the price of wool in the mid-1990s, AM became a widely accepted marketing tool. After 1994, the use of AM increased steadily among the woolgrowers interviewed (see Figure 2). According to Mrs Saxon, the increase in the use of AM after 1994 was influenced by a consensus among industry participants that greater transparency was needed along the wool supply chain. The Dorsets echoed Mrs Saxon's beliefs about AM becoming a standard requirement. However, Mr Dorset described the use of AM in this period as a means of avoiding discounts for untested wool, rather than subscribing to the notion of testing for greater transparency.

The case study farms tested 58–89% of their clip during this phase. The majority of the farms continued to test Merino fleece, weaner wool and pieces. However, they also began to test lower quality wool, such as bellies, locks and crutchings. Despite the increase in testing lower quality wool types in this phase, higher average prices were received for lots with AM across the six farms.

The Peppins tested 92% of their clip in 1996 after a dramatic reduction in the use of AM in the previous year when poor prices forced them out of the auction system (see Figure 2). They tested on average 80% of their clip each year from 1996 to 2003. Mr Peppin strongly believed it was the role of the grower to provide as much objective data on their clip as possible, despite the lack of premiums for tested wool.

As AM were increasingly embraced by woolgrowers after 1994 an industry norm emerged in which all sale lots offered at auction that were comprised of at least four bales of wool were tested at the wool brokers' request. All of the woolgrowers interviewed agreed they adopted the brokers 'four bale minimum' rule for AM. However, the auction data for the six farms did not support this statement. Although the average sale lot offered at auction with AM was larger than untested sale lots, all of the farms tested sale lots with fewer than four bales. According to the Saxons, Romneys, Polwarths and Coriedales, any lines with fewer than four bales offered with AM were tested in error by their brokers. However, the Dorsets and the Peppins tested superfine wool[7] in sale lots of less than four bales.

DISCUSSION

New insights into the agricultural innovation process can be derived from this case analysis of the enactment of AM technologies on-farm. In a general sense, it appears the insights are consistent with a sensemaking perspective of the enactment of a new technology. In this section the insights derived from the case analyses are presented in detail, along with their implications for researchers and practitioners. The sensemaking process of the adoption, implementation, use and abandonment of AM on-farm is discussed in this section in relation to the seven sensemaking properties described by Weick (1995).

The sensemaking concept of the enactment of sensible environments captures the notion that woolgrowers deliberately created an environment for the enactment of AM, rather than simply responding to it. The case study data suggested there were different perceptions and outcomes of the enactment of AM across the farms. Some woolgrowers saw their adoption and use of AM as a means of shaping perceptions of the quality of their wool and used AM in ways that promoted the perceived quality of their wool brand and their ram stud. Others saw the adoption and use of AM as a reaction to the influence of brokers and buyers. While these woolgrowers shaped their enactment of AM through their compliance with influential members of the industry, they did not perceive their adoption and implementation of AM strictly in those terms.

[7] Superfine wool – average fibre diameter of 17.6–18.5 μ.

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The case studies suggested the enactment of AM was also framed by the farm families' personal identity and social context.

A number of the farm families, who were confident of their ability to implement and use AM, revealed their social context and emerging industry belief systems prevented them from doing so in ways they would have liked. How the woolgrower interacted with their broker and the auction system influenced how they perceived their ability to shape the use of AM on-farm. A recurrent theme was the expansion of the use of AM across a range of wool types in response to demands from buyers and brokers, despite a lack of price premiums and a risk of additional discounts. These findings suggest sensemakers and their environment are co-created through the enactment of new technologies on-farm and lends support to Coughenour's (2003) research, which found people socially constructed their environment in response to agricultural innovation.

The issue of identity construction was significant for the families who enacted AM on-farm. However, the question as to whether these farm families constructed personal identity frames through the enactment of AM was not fully resolved in the study, although there is evidence that participants' personal identities influenced their behaviour towards AM. For example, the Coriedales identified themselves as owners of a high quality, established wool brand and ram stud and adopted AM to confirm this self identity. AM was adopted by the Coriedales in the absence of broker influence and market price premiums as they believed a ram stud of their quality and reputation should provide objective measurements of as many wool traits as possible.

The analysis depicted the enactment of AM on-farm as co-evolving with woolgrowers' personal identity frames. For example, despite woolgrowers and brokers articulating the 'minimum four bale rule' as the industry norm, smaller lots were routinely tested by the Dorsets and Peppins based on their experience that superfine wool would not be discounted for small lot size. Another example of the co-evolution of personal identity frames and technology enactment was Mr Peppin's shift from being an 'AM sceptic' to identifying with the role of woolgrowers as providers of objective measurements as his use of the technology increased.

If farmers' personal identities are to serve as a general orientation to the adoption and use of new technologies, technology developers and extensionists need to have an understanding of how these may influence behaviour towards new technologies and whether personal identity frames are confirmed or weakened though the adoption and use of the technology. An in-depth analysis of the personal identity frames of the potential adopters of new agricultural technologies would assist in the development of appropriate technologies and expose the perceived degree of risk and uncertainty associated with their enactment on-farm. An early assessment of the personal identity frames of potential technology adopters becomes even more important when it is realized every technology enactment situation is unique. However, as this study shows personal identity frames and the enactment of AM co-evolved, it is imperative technology developers consider the impact of such changes over time and are prepared to adapt technologies in response to them.

There was evidence of retrospection in the adoption and use of AM in the extent to which current projects and goals influenced the interpretation of the enactment of AM on-farm. For example, the Coriedales retrospectively justified their adoption and implementation of AM as a means of achieving their goal to be as objective as possible in the measurement of their wool attributes. This suggests woolgrowers' current goals and activities influence the sense they made of their actions towards AM.

The role of social context in the enactment of AM on-farm was highlighted by the influence of brokers on the adoption and use of AM. Woolgrowers engaged their brokers in an ongoing, evolving dialogue about the use of AM as a way of making sense of industry norms about the technologies. The Polwarths, Saxons, Dorsets and Peppins acted on their brokers' advice in the absence of experience with AM and clear market signals. These findings suggest that, in the absence of well-developed personal identity frames relating to a new technology, social influence and industry norms may drive technology adoption and use.

The data relating to the proportion of wool offered at auction with AM over time (see Figure 2) suggested the enactment of these technologies on-farm was ongoing. The cases also highlighted the impact events external to the farm business had on how woolgrowers made sense of AM. For example, in response to the collapse of the wool price and the abandonment of the WRPS in 1991, the case study farm families either abandoned AM or reduced testing.

The analysis suggested technology transfer did not simply result in a woolgrower's decision to adopt AM and make full use of those technologies on-farm. On the contrary, there was a broad range of technology actions, including the adoption, abandonment, readoption and implementation of AM over time. There was also evidence that the use of AM varied between the farms and was adapted over time in terms of the proportion, type, quality and value of the lots tested. The ongoing enactment of AM on-farm reflected a series of sensemaking cycles.

The case studies suggested the noticing and extraction of salient cues is a key issue in the enactment of new technology on-farm. Elements of conflicting social influence and ambiguity in market signals impacted on the salience of technology cues noticed by the farm families. In the passage of a busy and eventful wool production season, wool production and marketing cues relating to AM often went unnoticed. Similarly, ambiguous market signals made it difficult to judge which cues were salient to the adoption and use of AM as a lack of experience with these technologies contributed to difficulties in noticing salient cues.

Woolgrowers extracted different cues from the same 'events,' which resulted in different technology outcomes. For example, when brokers advised their clients to avoid testing relatively tender portions of their clip, five out of six participants complied. However, the Romneys interpreted this advice as meaning buyers may discount wool that was not tender if a woolgrower did not prove it was sound. As a result, the Romneys tested lots that were subjectively appraised as tender in order to prove that they may be sound.

The ability of the farm families to develop plausible explanations of AM in the early stages was constrained by a lack of experience and an absence of clear market signals. Any plausible explanations of AM were initially tested against the explanation of events made by wool brokers. A lack of trust in the auction system and buyers on the part of brokers and woolgrowers made any congruence of plausible explanations of AM suspect. When the explanations of others were in doubt and experience with AM was lacking, woolgrowers made plausible explanations of these technologies based on their assumptions, expectations and intuition.

CONCLUSIONS

In this study, sensemaking concepts were suggested as an explanation for how new agricultural technologies are enacted on-farm. This study showed the enactment of AM on-farm was an evolving, dynamic process that changed over time as woolgrowers made sense of these technologies in relation to their personal identity frames and social context, suggesting the enactment of new technologies on-farm can be conceptualized as a series of sensemaking cycles. These sensemaking concepts can be applied to examinations of the agricultural innovation process to provide a deep and rich explanation as to how agricultural technologies are adopted, abandoned, implemented and used. Studies of agricultural innovation that combine aspects of innovation behaviour prediction models, such as Rogers (2003) innovation-decision model, with the sensemaking concepts identified in this study (see Figure 1) and that use a combination of longitudinal, cross-sectional, qualitative and quantitative research methods, may help to provide more conclusive and generalizable evidence of how and why industry participants adopt and use new agricultural technologies.

These findings have important implications for the management of agricultural innovation. They suggest sensemaking in response to agricultural innovation needs to be seen as a purposive activity undertaken so industry participants can use technology effectively. That is, the effective use of new agricultural technologies is intrinsically linked to transitional environments and further technological advances. It can be argued that, during the development of new agricultural technologies, the focus needs to shift from the technological artefact itself to an understanding of how industry participants make sense of the technology in their own context. Technology developers and extensionists need to recognize end users are not necessarily interested in the physical technology or its functional characteristics *per se*; they are interested in the technology as a tool that helps them undertake their own work more effectively. The ability of participants in the agricultural innovation process (e.g. developers, extensionists, change agents and farmers) to collaborate on how a technology can be used in a way that is flexible and open to industry participants' sensemaking is a vital part of successful agricultural innovation.

The primary message to agricultural innovation researchers, technology developers, policy makers and extensionists is that the successful enactment of agricultural technologies on-farm requires the active, ongoing engagement of industry participants. In order to engage technology adopters and users in the innovation process, sensemakers' personal identity frames and social contexts and how these interpretation frameworks relate to the new technology need to be understood. The actions of

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developers and extensionists to engage end users need to evolve to meet new challenges as they arise through the process of enacting new technologies on-farm.

In other words, this case study suggests effective agricultural technology development, transfer and extension should start with an understanding of the social context of potential adopters and then their personal identity frames and perceptions of existing technologies and industry norms, rather than merely focusing on the development and transfer of the technology. In a similar vein, it appears the successful enactment of new agricultural technologies on-farm is more likely to occur when industry participants develop and present clear signals about the use and value of the technology on-farm so those signals can be extracted as salient cues by potential adopters and end users. Having funding and plans for technology development and transfer is not enough. The ability of developers and extensionists to recognize the cues to which end users will respond and to actively develop, articulate and manage those cues through a technology development, introduction and implementation process is also important.

In conclusion, this study lend support to calls for more flexible, collaborative and market-oriented approaches to agricultural innovation management (e.g Douthwaite, 1999; Douthwaite, Keatinge and Park, 2002; Sumberg and Reece, 2004). Flexible collaborative and market-oriented innovation models, often referred to as the 'fourth generation' of research and development (R&D) management approaches (Miller and Morris, 1998), emerged in the corporate research sphere in the 1980s and include systematic links between researchers in the public and private sectors and alliances between producers and end users. Such approaches to innovation management seek to incorporate the knowledge researchers, users, suppliers, producers and competitors have in an expanded and boundary-spanning innovation arena (Niosi, 1999; Miller and Morris, 1998). In fourth generation R&D management approaches, innovation is seen to occur within a network of relationships within which the outcomes of innovation initiatives depend to a great extent on the performance of other actors who are involved directly and indirectly in the innovation process (Miller and Morris, 1998). These flexible and collaborative innovation models emphasize direct collaboration with end-users and the rapid evaluation of the performance of new technologies *in situ* (Miller and Morris, 1998; Niosi, 1999). The incorporation of the sensemaking concepts described in this study in such approaches to agricultural innovation management can be used to deepen the understanding developers and extensionists have of technology end users and to better establish and manage collaborative relationships with them during the development, adoption and implementation of new agricultural technologies.

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