Innovative precision dairy systems:
A case study of farmer learning and technology co-development

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Abstract

Precision farming, a concept based on information intensive management using IT-related devices, presents an opportunity for agriculture to embrace the information age. However, uptake of precision farming in Australia and internationally has been lower than expected. A possible reason for this is a historical focus on development of technological devices rather than on development of farmers as skilled end-users. Understanding the processes involved in farmer learning of, and adaptation to, precision farming practice is an important first step in creating conditions for innovative precision farming systems. The aim of this study was to identify the features associated with farmer learning and adaptation in Australian precision dairy systems. Qualitative research methods were used to provide a rich picture of the experiences of farmers who had invested in technology for identifying individual cows, measuring their daily milk yield, applying individual grain concentrate feeding, and implementing associated management control over the farm system.

The results showed that dairy farmers implementing precision dairy systems encounter a learning process characterised by three main phases: an early learning phase, a consolidation phase, and an advanced user phase. The technological systems researched in this study were underutilised by farmers due to a failure to move from the consolidation phase to more advanced practice.

Learning processes within precision dairy systems did not go far enough in empowering farmers to be self-learners. Recognition of the importance of three core competencies (ICT skills, engagement, and knowledge transfer) for farmer integration of precision dairy practice would help retailers tailor training to specific farmer characteristics.

A focus on the devices of precision dairy farming undervalues the role of farmers as co-developers of precision dairying systems. On-farm adaptation of material technology, and precision dairy practice, is the key to development of these
systems. The practice-based knowledge created by farmers is where the precision farming goals of increased farming system control and increased efficiency of production are met.

Development of innovative precision dairy systems relies on recognition of farmers as co-developers. Further to this, innovation is driven not just by farmers but by the network of people who operate around them in a community of practice. Strengthening the linkages between community members, and facilitating knowledge transfer around the community (for example from farmer to retailer to developer) is central to innovation in precision dairy systems.

Continual on-farm development of precision dairy systems was observed from which lessons could be harnessed to benefit the wider dairy industry. Explicit acknowledgement of users as co-developers, along with a corresponding strengthening of feedback mechanisms to facilitate transfer of on-farm learning back to national and global retailers, are required to enhance knowledge transfer within precision farming networks.
Declaration

This is to certify that

(i) the thesis comprises only my original work towards the PhD except where indicated in the Preface
(ii) due acknowledgement has been made in the text to all other material used
(iii) the thesis is less than 100,000 words in length, exclusive of tables, maps, bibliographies and appendices.

Callum Ross Eastwood
Acknowledgements

Arriving at Melbourne airport in 2004 I was picked up by Dave Chapman, our first face to face meeting, and later that day I met Mark Paine for the first time also. I’d like to sincerely thank both Dave and Mark for taking me on as a PhD student sight unseen and I hope I have in some way proven this blind faith. Their supervision was supportive without being overbearing, they were there when I needed help but I was also able to manage my own project which I think is an invaluable lesson for any postgraduate. So my first thanks are to my supervisors for the academic support but also for providing an outlet for rugby discussions!

Dairy Australia were similarly supportive during my PhD, providing funding but also opportunities to attend conferences and be involved in other projects. It is through Dairy Australia that I have become to feel a part of the wider dairy community.

The Melbourne School of Land and Environment (formerly Land and Food Resources) has provided me with many friends and colleagues. It also provided me with my primary stipend, via the Alton Gould Edmonds scholarship. I’d like to acknowledge the support of the School in providing me with the means to undertake this work.

I arrived from New Zealand knowing no one and have made many great friends during my PhD. Outside of the Uni, Fiona and Celia were my primary links to the real world and great outlets for non-PhD discussions. JP and Jo were great flatmates for much of my study. Yinn was there through the days where writing drove me to distraction. Within Uni, Lucia became a mentor, and Matt and Jack were more rugby outlets for me. Alison L and Alison O were friends throughout while latterly Chela, Brent, Adelene and Wei Wei provided a reason to come to the office each day. Yu Pei also became a great Facebook buddy with whom I could share the highs and lows of writing. Martin, Ned, Mick, and Sev were there for adventures in Victoria, across Australia, New Zealand, Slovakia, and Switzerland – along with the occasional bottle of cheap wine in Melbourne and discussions on epistemologies. Abi struggled through the PhD process with me, and was the
inspiration for nicknaming my thesis Daisy, a name that stuck with all of my friends. My family waited patiently for me to finish, working out that sometimes asking how Daisy was going wasn’t the best discussion topic, but thanks Mum, Dad, Sash and Brooke for your support.

Mostly I’d like to thank the farmers and other dairy industry personnel who helped me during my study. I learnt a lot from my interaction with them and took away a respect for how they managed their businesses in the face of significant uncertainty. I appreciate the time they all gave for my work, and the enthusiasm with which they discussed their precision farming practice.
Acronyms and common terms

Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>EID</td>
<td>Electronic identification</td>
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<tr>
<td>ICT</td>
<td>Information and communication technology</td>
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<tr>
<td>PA</td>
<td>Precision agriculture</td>
</tr>
<tr>
<td>PDF</td>
<td>Precision dairy farming</td>
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<tr>
<td>PDS</td>
<td>Precision dairy systems</td>
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<tr>
<td>PDF-ICT</td>
<td>Precision dairy farming-information and communication technology - Defined as the hardware and software associated with precision dairy farming, for example inline milk sensors, herd management software, and electronic identification systems.</td>
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Common terms used

Retailers  This term is used to describe commercial retailers of precision dairy farm technology, and covers salespeople and retailers at local, national, and international levels.

Entry level PDF-ICT As described in Chapter 2, entry level PDF-ICT involves less expensive technology, often without data capture devices.

Advanced PDF-ICT As described in Chapter 2, advanced PDF-ICT is more expensive technology with advanced software and data capture devices.

Reports  In this thesis ‘reports’ relates to pre-set management reports produced using herd management software.

Herringbone shed Cows enter in single file and assemble either side of a central pit where the milking equipment is located. Cows can stand perpendicular to the pit, or on an angle.

Swingover shed Swingover dairy sheds have a herringbone layout, but the same milking equipment services both sides of the pit, by swinging to either side.

Rotary shed Cows enter into empty bails on a large moving circular platform and are milked as the platform rotates. Milked cows leave when they pass the exit.
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1.
Precision dairying: discrete devices or management systems?

1.1 Introduction – the problematic context

The information age has had a dramatic impact on most sectors of the global economy but agricultural industries have generally been slow in shifting their focus. This trend holds true in Australia, where only 56 percent of farms used a computer as part of their business operations in 2004/05 (ABS 2006) compared to 89 percent of Australian businesses in 2005/06 (ABS 2007). Reasons suggested for slow uptake of information technology (IT) in agriculture include low computer literacy along with farmer perceptions of lack of benefits and in compatibility with management systems (Stubbs et al. 1998).

Precision farming, a concept primarily based on the collection of information using IT-related devices, is a key vehicle for agriculture to embrace the information age. However, uptake of precision farming in Australia and internationally has been lower than expected (Daberkow & McBride 2003; Robertson et al. 2007). A possible reason for this lies in the techno-centric focus of the concept, where research and development focuses on the device rather than the management system within which the device will be used. Schmoldt (2001, p.6) emphasised this mindset in stating:

‘Eventual implementation of precision agriculture technologies will be largely economic. Because information has a benefit and a cost, the former must outweigh the latter’

At one level Schmoldt is correct, but there are other important factors involved which have often been overlooked in two decades of precision farming as a specific concept. Uptake is different from implementation because installing
precision farming devices is just the start point. Return on investment is only achieved through subsequent improvement in the farming system and it is here that people are the key.

In the area of precision livestock farming (PLF) the focus on technology as a device is just as apparent. Berckmans (2008, p.1) explains PLF as:

‘monitoring, collecting and evaluating data from on-going processes. Collection of data from animals and their environment, by innovative, simple and low-cost techniques, is followed by evaluation of the data by using knowledge-based computer models... currently, considerable PLF research is directed toward development and validation of various techniques for data measuring and registration on livestock farms.’

While precision farming is based around the idea of increased system control through use of such devices, farmers face significant challenges in learning to use the devices and adapting their farming systems accordingly. Kitchen et al. (2002) identified access to quality education and training as constraints to implementation of precision farming, however there is little published information exploring such implementation constraints in depth. The research presented in this thesis aimed to explore the reasons behind poor implementation of precision farming in the ‘real world’.

1.2 Research questions and approach

Learning and adaptation processes of precision farmers were investigated using precision dairy systems in Australia as a case study. The three major components in this study (see below) were guided by specific research questions which are listed in the relevant chapters. All the research components were situated within the following high level research questions.

1. What are the processes driving farmer learning within Australian precision dairy systems?
2. What is the role of on-farm adaptation in development of precision dairy systems in Australia?
3. What are key factors for the further development of innovative precision dairy systems in Australia?
1.3 Research perspective

Qualitative methods were used to facilitate exploration of issues facing precision dairy farmers. A grounded theory approach (Bryman 2001) was adopted as it fitted well with a subject that had received little prior research attention. As a consequence the research presented in this thesis takes the form of applied farming systems analysis.

1.4 Outline of thesis

This opening chapter has set the scene for the underlying problem statement guiding research presented in the thesis. The overall study consisted of three phases (scoping study, case studies, and conjoint analysis) which is represented in the chapter structure of this thesis:

Chapter 2: The importance of information in agriculture and the concept of precision farming are presented in the first half of this chapter. In the remainder of Chapter 2 the results from a scoping study of precision dairy farmers are discussed. These results provide the focus for the six farm case studies described in Chapters 4 and 5.

Chapter 3: Theoretical perspectives around learning and adaptation are discussed prior to development of the objectives and method used in six farm case studies. Note that while the theoretical discussion is presented prior to the case study chapter, this does not reflect the actual order in which research was conducted. Theoretical analysis was conducted after the case study research, but is presented first for the reader’s benefit.

Chapter 4: Findings from exploratory research involving six case studies of Australian precision dairy systems are presented and discussed. Chapter 4 forms the foundation of the overall study, describing fieldwork which spanned two years, and ends with a discussion of the findings in relation to theoretical perspectives presented in Chapter 3.
Chapter 5: A cross-case analysis is presented, building on the findings presented in Chapter 4. Processes associated with learning and adaptation are analysed using the community of practice concept (Wenger, 1998) as a lens.

Chapter 6: Trade-offs between precision dairy devices and the transaction costs associated with learning and adaptation are presented and discussed. Chapter 6 includes specific findings from the six farm case studies, along with additional research in the form of a conjoint analysis of experienced precision dairy farmers.

Chapter 7: The research findings are drawn together and contextualised in this concluding chapter.
2.
Precision dairy farming: in concept and practice

2.1 Introduction
Precision agriculture, or precision farming, has been recognised as a specific farm management approach for almost two decades (Fairchild 1988, in Stafford 2000). In this chapter the concept of precision farming is discussed in relation to its application in Australian dairy farming. Current and future uses of precision technologies in dairy farming are outlined and related to the information requirements of dairy farmer decision making. The pivotal role of information and communications technology (ICT) is acknowledged with a theoretical discussion of what information and technology involve as individual concepts. Results from a scoping study, designed to investigate issues surrounding current and future utilisation of precision technologies on Australian dairy farms, are presented and reviewed. At the conclusion of this chapter, emergent themes from the scoping study are discussed and used to guide the remainder of the overall study.

2.2 The precision dairy farming concept

2.2.1 Defining precision dairy farming
The farm management concept of ‘precision agriculture’ (PA) entails managing land according to its specific characteristics (Cox 2003) with the core goals of increased production, reduced input costs, and reduced environmental impacts (Cowan 2000). These goals are achieved through utilisation of information technology to measure and manage the inherent variability within land-based production systems.Precision agriculture is not a new concept, according to Cox
(2003) ‘small farmers have utilised precision agriculture for millennia through intimate knowledge of local variations in their fields’ but increasingly large modern farming operations have created a disconnect between the manager and units of production. Underlying precision agriculture systems is the assumption that ‘more and better information can reduce uncertainty in decision making and unmeasured variability in agronomic conditions’ (NRC 1997).

Originally focussed on cropping practice, the precision agriculture philosophy has recently extended to include livestock farming, of which precision dairy farming (PDF) is a subset. Whereas in arable systems this variability is very much centred on the soil and plant resources, in dairy farming an important source of production variability is also the individual cow. Global Positioning Systems (GPS) revolutionised arable farming by facilitating greater site-specific management by the late 1980s, yet Cox (2003) points to the lack of a comparable single pivotal technology to enable use of the precision paradigm in livestock farming. Rather a host of technologies are considered to be relevant to PDF including electronic animal identification, in-line milk sensors, decision support software, hand held computers, robotic milking, spatial land resource mapping, geographic information systems, variable rate technology for fertiliser and irrigation application, and spatially-based pasture sensors.

Definitions of the precision agriculture concept vary in published literature (e.g. Blake et al. 2003; Bootle 2002; Pierce & Nowak 1999) however several common themes are present. The underlying mechanism is information technology, both for data collection and interpretation; the phenomenon being measured is variability; the issue of scale is important; and the outcome is improved management control. In the dairy sector Spilke and Fahr (2003) identify PDF as a concept primarily based on data collection related to individual animals. Maltz (2000, p.133) also alludes to an animal-centric definition, stating:

‘The smallest production unit in the dairy is the individual cow. Precision agriculture aims to manage the basic production unit in order to exploit its maximal production capacity. Nevertheless, under conventional conditions, feeding and milking management is usually executed for the whole herd or for a group of cows.’
A focus on the animal as the unit of production may fit well with intensive dairy farming systems in Europe but the pasture-based nature of Australasian dairy farms requires a broader perspective to encompass forage production. Taking this into account the following working definition of precision dairy farming in Australia is proposed for the purposes of this study:

The use of information and communication technologies for improved control of fine-scale animal and physical resource variability to optimise economic, social, and environmental farm performance.

Becoming a precision dairy farmer does not represent a conscious mindset shift. Rather it occurs as a consequence of a drive to improve the management approach, as discussed later in this chapter. Precision dairy farming is currently a classification used by researchers rather than by the farmers themselves and its subjective delineation makes it difficult to determine exactly when someone becomes a ‘precision dairy farmer’. Therefore the above definition is useful for providing an initial point of reference for delineating precision farmers and to provide a boundary for this research study. Under this definition an example of precision dairying could involve using daily measurement of individual cow milk yields to set supplementary feeding rates. Whereas setting feeding rates based on monthly milk yields (from herd test data) would fall outside the definition of precision dairying due the coarse temporal scale.

Precision dairy farming is applicable to both animal and feed production subsystems (Cox 2003). In Australia, individual cow management is typically the first step dairy farmers take towards precision farming due to the presence of established commercial products, for example milk meters and activity sensors. Also, Australian farmers are experienced with the individual animal management mindset from their use of herd testing data for breeding and culling decision-making, and therefore the shift to precision farming represents more evolution than revolution. An area where precision technologies are currently less advanced is in the feed production subsystem involving pasture production and utilisation, and nutrient management.
2.3 Precision farming: Of devices, information and people

2.3.1 Introduction

Precision farming as a concept was defined in the previous section, with ICT and information highlighted as key components. These facets are further defined and explored in this section with respect to their role in enhanced farmer decision-making. The collection of data is highlighted as only a step on the path to knowledge creation, and it is suggested that hardware and software devices have limitations in the application of knowledge and wisdom to decision-making problems. Precision farming is presented as being greater than the devices which collect and manage data with farmers, as end users of the data, being integral to achieving farm management system change. Finally, the potential for precision farming is outlined in respect to current information requirements and patterns of use in dairy farm businesses.

2.3.2 Information and communication technology (ICT)

In the precision farming definition proposed earlier, information and communications technology is a key feature. Information technology (IT), defined as the use of computers and software to disseminate, process, and store information (Oxford English Dictionary 2008), is the basis for precision farming components. Haag et al. (2007) viewed IT more holistically, as a ‘mind support tool set’ where the tools help people work and process information. The human-computer interaction inherent in IT-based precision systems is described by Leeuwis (1993) as a ‘communication of meanings’. Acknowledging the abundance of terms used to describe computer-based management aids, Leeuwis settled on ‘communication technologies’ (CT) to reflect communication of meanings, a multi-directional data flow between different IT components and also between computers and people. In the last decade the convergence of information technology and communications technology has been given a new label of information and communications technology (ICT). ICT is used to represent the
various forms of dairy information systems discussed in this thesis as it best reflects the intersection of hardware, software, and people.

2.3.3 Information and decision making in dairying

Knowledge management theory

Precision farming is based around the collection of data using ICT but does this necessarily translate into more complete knowledge for decision making? Stair and Reynolds (1999, p. 135) suggest this is not the case in respect to the use of ICT in firms, proposing a distinction between data and information:

‘The bane of modern business is too much data, not enough information. Computers are everywhere, accumulating gigabytes galore. Yet it only seems harder to find the forest for the trees.’

Davis and Olsen (1985) categorised data as being raw facts and figures, and information as that which is used to make decisions. Ackoff (1989) took this idea further and proposed a continuum of data, information, knowledge, understanding, and wisdom where each stage requires adding value over the previous stage:

Data: symbols that represent properties of objects and events in the form of raw observations or measurements;
Information: consists of processed data, analysing connections between data, for example organising data into tables and graphs. Answers questions that begin with who, what, when, where, how many;
Knowledge: involves use of information for action, answers how-to questions;
Understanding: conveyed by explanations, answers why questions. The difference between understanding and knowledge is the same as learning and memorising;
Wisdom: involves exercise of judgement, deals with values, and is a human evaluation of effectiveness that cannot be programmed into computers. Wisdom is created through use of knowledge, through the communication of knowledge users, and through reflection.
Bellinger et al. (2004) contended that the sequence is less involved than Ackoff proposed and that understanding is actually interwoven into a ‘DIKW’ model and is required for transition between each of the steps (Figure 2.1). Harsh et al. (1981) proposed another perspective on information that delineated between descriptive information (‘what is’, the state of the business); diagnostic information (‘what is wrong’, what is – what ought to be); predictive information (‘what if’); and prescriptive information (‘what should be done’) (Table 2.1).

**Table 2.1: Information hierarchies and applicable information system phases**

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<tr>
<td>Wisdom</td>
<td>Wisdom</td>
<td>Prescriptive</td>
<td>Expert systems</td>
</tr>
</tbody>
</table>
In general the DIKW model, regardless of its specific components, highlights the process of taking simple pieces of data and continually adding value until wisdom is created. At each step up the hierarchy more human input is required, and potential computer input reduces (Rowley 2007). As a consequence, lower levels of the hierarchy are most programmable for information systems, with the higher levels requiring much more complex modelling of human and environmental processes (Table 2.1). Harsh (2005) identified the upper levels of the hierarchy, knowledge and wisdom, as key areas on which to concentrate information systems in the future.

Wisdom, according to Ackoff (1989), is an inherently anthropocentric process. It involves application of beliefs, values, and experience to knowledge, usually in order to address questions with no distinct right or wrong answer. Rowley (2007) suggested that expert systems can assume the role of humans in applying wisdom, however this seems to adopt a simplistic and mechanistic overestimation of ICT's ability to perform cognitive functions. Bellinger et al. (2004) state that computers will never have the ability to possess wisdom, as it is a uniquely human state. Claiming that ICT-based decision support systems are equipped to address semi and/or ill structured issues is ‘problematic’ according to Leeuwis (1993). He argued that ICT characteristics are socially negotiated and context specific, featuring an internal design (software and hardware dimensions) and external design involving a societal code with normative and political dimensions. It is imperative therefore to understand learning processes underpinning the complex wisdom stage, and to investigate the DIKW model in respect to the ICT-human interaction.

Knowledge itself can take one of two forms: either tacit, a subjective form of knowledge gained from experience and practice; or explicit, an objective form of knowledge based on theory and rationality (Harsh 2005; Nonaka & Takeushi 1995) and this is discussed further in section 3.2.2. Tacit knowledge can influenced by the variety of an individuals experience and the subsequent knowledge of the experience (Nonaka 1994) and be difficult to share with others. In using tacit knowledge a person may not be able to specifically define the basis for their decision making process. Nonaka and Takeuchi (1995) break tacit knowledge into
technical and cognitive dimensions, where the former encompasses informal skills and ‘know-how’ and the latter involves mental models and beliefs inherent in an individual’s perception of the world around them. Explicit knowledge, in contrast, is more definable and can be recorded or expressed to others.

Computerised knowledge management and decision support systems are largely confined to operating in the explicit knowledge domain. This is because explicit knowledge can be more readily stored, processed, and exchanged in an ICT system. However this can be in conflict with the highly tacit decision making processes of farmers. Harsh (2005) pointed to the challenge of designing information systems to facilitate effective tacit knowledge sharing.

**Information requirements for dairy farmer decision making**

As enterprise managers, dairy farmers attempt to organise available resources to achieve their business goals. The natural systems in which they operate are highly uncertain due to physical resource variability on farm in addition to variability in off-farm factors such as international prices for dairy products. Through their management strategies, farmers aim to exert control over on-farm system variability. Control is a key management function, along with planning and implementation (Parker 1999), and involves monitoring, comparing, and correcting management plans. Information gathering is a vital component in the control function and in reducing system uncertainty. ICT systems are applicable to planning and implementation, in addition to control functions of management, as they help to gather and organise information for farmers.

Haag *et al.* (2007) and Leeuwis (1993) delineate between structured and non-structured decisions. The former require little intuition and involve information processing to get one right answer, while the latter may involve several right answers with no precise way to get the answers. While most decisions fall between structured and unstructured, it is the more structured decisions which lend themselves to programming of decision support systems. In their discussion on information management differences between farmers, Fountas *et al.* (2006) cited a range from ‘information hogs’ who seek and use large amounts of data, to ‘seat of the pants’ farmers where experience and intuition are key factors. However
the processes driving intuitive farmers are not fully understood by researchers or farm advisors (Fountas et al. 2006) and therefore accounting for them in ICT decision support tool design is difficult.

In their review of Management Information Systems (MIS) theory, Fountas et al. (2006) listed the key questions for information gathering and use, and therefore subsequent design of MIS: what information is needed, when is the information needed, who needs it, where is it needed, why is it needed, and how much does it cost? These questions can also be applied to design of precision dairy systems, and the ICT which underpins them. Similarly, Haag et al. (2007) outlined the features of an 'information literate knowledge worker' as being able to define what information they need, know how and where to obtain information, and to understand information once they receive it. The goal is to use the information to enable the organisation achieve the greatest advantage. Precision dairy systems involve enhanced information management and decision-making processes and this requires an 'information literate farmer', who is able to address key questions such as those proposed by Fountas et al. (2006) and Haag et al. (2007).

Information exists at different scales of granularity, from very fine detail to coarser highly summarised information (Haag et al. 2007). The information required for dairy decision making differs in granularity depending on whether it is used for operational, tactical, or strategic management. For example tactical level information is more specific and quantitative than that used for strategic management (Gray 2001). New Zealand dairy farmers exhibit use of different information granularity to triangulate around single decisions, for example use of daily visual assessment, weekly pasture scoring, and fortnightly falling plate meters to monitor average pasture cover (ibid.).

Information requirements, based on key dairy decision-making areas, have been assessed by several authors (Table 2.2). Huirne et al. (1997) examined general critical success factors for Dutch and US dairy farms and related them to information needs citing four main decision categories. More detail on production and feeding was provided by van Asseldonk et al. (1999b) who listed six key dairy farm operational management categories where Dutch farmers require information.
A review of Gray’s (2001) performance indicators for New Zealand dairy systems shows similar information requirements to those in Europe but with greater focus on feed production and less focus on cow health. There are also obvious differences in terminology, for example field scoring would equate to pasture measurement and field administration would be similar to paddock rotation policy. Australian dairy systems have similar information requirements to those suggested by Gray (2001), with an additional focus on supplements such as grain, and total mixed rations.

**Table 2.2: Deconstruction of dairy farmer information requirements**

<table>
<thead>
<tr>
<th>Critical success factors (Huirne et al. 1997)</th>
<th>Operational information requirements (van Asseldonk et al. 1999b)</th>
<th>Performance indicators (Gray 2001)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Financial factors</strong></td>
<td><strong>1. Reproduction</strong></td>
<td><strong>1. Market</strong></td>
</tr>
<tr>
<td>Net farm results, Margin per 100kg of milk, fixed and variable costs, equity, net profit</td>
<td>Record keeping, oestrus, insemination, conception, sire selection</td>
<td><em>Output prices</em></td>
</tr>
<tr>
<td><strong>2. Milk production</strong></td>
<td><strong>2. Health care</strong></td>
<td><em>Stock price, milk price</em></td>
</tr>
<tr>
<td>Control of feed costs, Milk production per cow, Balancing feeding rations, Care for young stock, Milk quality</td>
<td>Clinical/subclinical mastitis, subclinical mastitis, other infections, metabolic disorders, leg/hoof disorders, examination, treatment</td>
<td><em>Input prices</em></td>
</tr>
<tr>
<td><strong>3. Feed and roughage production</strong></td>
<td><strong>3. Milk production</strong></td>
<td><em>Fertiliser, grazing, maize, standing pasture</em></td>
</tr>
<tr>
<td>Pasture quality, Quality home produced roughage, Timely mowing/harvesting, Planning cows using pasture, Fertiliser per ha</td>
<td>Milking, milk measurement and composition, cell count, other milk parameters, milk delivery</td>
<td><strong>2. Feed</strong></td>
</tr>
<tr>
<td><strong>4. Marketing</strong></td>
<td><strong>4. Nutrition</strong></td>
<td><em>Pasture</em></td>
</tr>
<tr>
<td>Cost price of milk, growth of farm size, anticipating changing markets in future, costs of labour and machinery, price purchased milk quotas</td>
<td>Feed calculation and administration, ration composition, feeding</td>
<td>Quality, quantity, grazing duration</td>
</tr>
<tr>
<td><strong>5. Cattle replacement</strong></td>
<td><strong>5. Cattle replacement</strong></td>
<td><em>Supplement</em></td>
</tr>
<tr>
<td>Herd dynamics, replacement</td>
<td></td>
<td>Forage crops (yield, quality, growth, maturity), and silage (yield, quality)</td>
</tr>
<tr>
<td><strong>6. Roughage production</strong></td>
<td><strong>6. Roughage production</strong></td>
<td><strong>3. Livestock</strong></td>
</tr>
<tr>
<td>Field scoring, manure use, grass supply, grassland management, field administration</td>
<td>Field scoring, manure use, grass supply, grassland management, field administration</td>
<td><em>Production</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pregnancy status, condition score, milk (quality/quantity)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Feed demand</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cow intake, intake/ha/day, stock number</td>
</tr>
</tbody>
</table>

The information requirements listed in Table 2.2 highlight the range of factors dairy farmers need to consider when applying management control to their system. It emphasises the opportunities for precision technologies to collect and collate objective data for farmers in order to streamline management systems and
increase production efficiency. Precision dairy farming ICT (PDF-ICT) is used to identify performance indicators which are outside set parameters, an approach termed 'management by exception'. For example a PDF-ICT system can alert a farmer when an individual cow's milk yield drops by over 20 percent. However, this approach requires farmers to be aware of, and be able to elucidate, the thresholds and information they use when making decisions in order to set ICT-based parameters.

**Collection of objective data in dairy systems**

Formal and objective tools have not been widely adopted in Australian dairy systems. Pasture-based dairy farmers often rely on tacit or subjective knowledge systems, built through experience and observation, for farm monitoring and evaluation because they are considered to be timely, rapid, and require no capital outlay (Gray 2001). Formal pasture recording is rare on Australian dairy farms even though Garcia and Fulkerson (2005) stated that accurate daily pasture allocation could result in a 10 percent increase in milk production. Where objective tools are used these may be replaced with subjective measures once a farmer feels they have calibrated visual cues to the objective standards (Parker 1999). An example of this is the use of rising plate meters for pasture measurement, where plate meters are often used until the farmer feels comfortable with the accuracy of their visual judgement of quantity. Leewis (1993) found that Dutch farmers became 'bored' with ICT and internalised the useful elements, or information needs changed faster than the ICT. Parker (1999) identified low use of formal monitoring in New Zealand pasture based agriculture and provided six main reasons for this:

1. Visual assessment has proven adequate for achieving production and financial goals
2. Formal monitoring is discontinued once the skills are learnt
3. No clear link exists between the formal indicators and farm business strategy or the farmer’s goals
4. The economic benefits of monitoring are unclear
5. There is inadequate data processing and interpretation support
6. The individuals who propose formal monitoring systems and associated
decision support systems often have a poor appreciation of a farmer’s world
view

More objective measurement is employed in animal monitoring but there is still
considerable expansion potential. In small hand-milked herds of the early 1900s,
visual monitoring could be relied upon to adequately determine cow production
and health. Rising herd sizes and adoption of advanced milking technology over
the past 50 years has continually reduced per cow contact time at milking yet
subjective measures of performance remain prevalent. In current Australian dairy
systems, production and health information is obtained either visually, at an
individual cow level via herd testing, or at a herd level via milk company quantity
and quality tests. Approximately 50 percent of Australian dairy cows are herd
tested monthly (ADHS 2005) primarily for identification of cows with high somatic
cell counts. Data from herd recording represents the main objective form of cow
production and health information collected on Australian dairy farms. However,
the infrequent (monthly) recording renders the data unsuitable for use in
operational decision making such as feeding to production in all but a few days
after each herd test. In the future, dairy decision making will most likely be based
on more objective data to improve efficiency of production.

**Improving control in decision-making with precision farming system**

Farmers often make decisions using incomplete data and in conditions of
significant uncertainty (Thysen 2000). Precision systems are used to address this
uncertainty by improving control via increased use of objective data (Jongebreur
2000). It is an information rich approach to management and this can present
specific challenges to farmers used to tacit knowledge based management
systems. Cox (2003) outlined the two ways ICT-derived data can be used: either to
monitor and control machines and equipment, or to provide inputs for management
decision making. The latter leads to a key proposition for this study; that by using
ICT, more data can be collected but management change only occurs when the
farmer takes the data and applies it in decision-making. This requires farmers to
contextualise the data and add their own experience to convert basic data into
knowledge or wisdom, as expressed in Ackoff’s (1989) DIKW hierarchy. In the next
section the current on-farm application of precision dairy farming is outlined, along with the challenges that must be met to achieve greater uptake of the practice.

### 2.3.4 Precision technology in a system context

Precision farming is highly techno-centric, however the role of the farmers who use the technology and information should not be understated. Definitions for technology vary from being focussed on use of a material object to being very broad in scope. MacKenzie and Wajcman (1985) describe technology as consisting of three layers or dimensions. The first layer involves physical objects and artefacts; the second relates to activities or processes; and the third to what people know and do. Farrington and Bebbington (1993, in Paine 1997) express a similar three tiered definition referring to components of hardware, methods, and knowledge. These definitions emphasise an interaction between ideas, material objects, and humans in a system designed to accomplish a task.

Perceiving technology in a whole system sense, rather than just the physical components, fits well with the precision farming concept and helps to provide insights into its limited uptake and implementation. Precision farming originated in the research and extension domain and often represents technology-push (Bell 2002) of scientists and developers as opposed to technology-pull driven by farmer demand. This approach suffers from a techno-centric mindset where there is a focus on technology as hardware rather than technology as a system involving farmers, knowledge, and learning. An alternative paradigm is suggested by Williams and Edge (2005) who describe technology as a social product and therefore patterned by the conditions of its creation and use. The actual decision maker is an often overlooked aspect in the design of decision support systems (Harsh 2005). This failure to consider the actual use and decision making processes of the end user in the creation of precision technologies will hinder successful implementation.

By viewing precision technology as more than a combination of technical devices, the importance of the end-user, the farmer, becomes apparent. Explicitly including
farmers in a more holistic view of technology links them into the creation of innovative precision farming systems.

2.4 Current and future precision dairy practice

2.4.1 Drivers for Australian precision dairy systems

Precision dairying is uncommon in Australia but has been practiced in European housed systems and North American feedlot dairy systems for over 20 years. Australian dairy farming systems stand apart from those in Europe and North America due to a reliance on grazed pasture and focus on per hectare rather than per cow production (Shephard 2004). While the importance of pasture as the feed base is still paramount, supplementary feeds are increasingly being used to maximise cow production and fill short-term feed gaps. Currently farmers are offering cows concentrate levels of up to 3 t DM/cow/year (Wales et al. 2006) while the Australian average was 1.45 t DM/cow/year in 2007 (Dairy Australia 2007). This mix of pasture and supplementary feeding opens the door for adoption of precision farming systems to maximise utilisation of expensive purchased feeds via individual feeding.

Australian dairy systems are primarily family owned and operated: 61 percent employ only family labour (Dairy Australia 2005). In line with international trends, the total number of Australian dairy farms has been decreasing (20,000 in 1980 to under 10,000 in 2004), average herd size is increasing (85 cows/farm in 1980 to 242 cows/farm in 2006), and the number of very large herds (over 1000 cows) is also on the rise (Dairy Australia 2006). In recent years, farms have been under increased pressure from drought and deregulation, and a cost-price squeeze (rising input costs and steady or falling commodity prices) is driving a continual search for efficiency gains (Garcia & Fulkerson 2005). In such an environment, it is not surprising that ABARE (2002) suggest that those farmers left in the industry will only remain viable by increasing herd size, farm size, and adopting more intensive production practices.
Increasing herd size has been associated with specific challenges for farm management, such as a diminished ability for farmers to use memory-based systems to collect pertinent information about particular cows (Rossing 1999). Electronic identification (EID) systems have provided a technological approach to the previously intuitive process of individual cow management (Reid 2003). EID facilitates use of associated cow monitoring and management technologies such as milk quantity and quality sensors, activity monitoring, individual feeding, and automated drafting. In 2000 the National Livestock Identification Scheme (NLIS) made the use of radio-frequency identification (RFID) tags compulsory in all cattle in Victoria and NSW. The subsequent widespread tagging of cows with RFID has created a pathway for greater uptake of individual cow monitoring by providing farmers with a low cost entry point, and by providing ICT developers with a technology on which to base their systems.

Dairying in Australia faces serious labour issues in terms of time demands upon farmers and their families, cost of paid labour, and difficulties in attracting and retaining staff due to long working hours and repetitive tasks. Labour accounts for over 20 percent of milk production costs on Australian farms and labour efficiency is considered by Garcia and Fulkerson (2005) to be a key factor in future dairy industry growth. Precision technologies can increase efficiency through reduction of operational labour requirements, and a technologically-advanced dairy could prove more attractive to younger staff.

The drivers of increasing herd size, increased use of supplements, labour costs, uptake of on-farm IT, and the NLIS scheme, combined with a continual search for efficiency gains, indicate that management at the individual animal level will have a significant future in the Australian dairy industry. Use of precision tools for managing feed production is currently limited but there is significant potential for their use in optimising pasture growth and utilisation. Future off-farm factors potentially influencing precision dairy farming uptake include product traceability and market access issues.

The benefits of PDF are similar to those observed in a Productivity Commission (2004) study of Australian firms using ICT which found performance benefits from
access to more accurate, timely, and useful information. The study identified six key areas where ICT improved performance, of which the areas of labour, production and distribution processes, management practices, and relationship with customers and suppliers would be of possible relevance to dairy farm management.

### 2.4.2 Precision dairy systems in Australia

Little published information exists on the occurrence or composition of precision dairy systems in Australia. Klindworth and Greenall (2004) surveyed Australian dairy farms and found 13 percent used EID, 8 percent automatic drafting, 4 percent activity sensors, 9 percent computer-based feeding, and 28 percent automatic cup removers (ACR). Another survey of Australian dairy farmers in 2005 found 25 percent use of microchip tags (EID), 25 percent use of ACRs, and 9 percent use of computerised feeding (Lubulwa & Shafron, 2007). ACR use and the level of computerised feeding had increased from 14 and 0 percent respectively in 1992 (Lubulwa & Shafron 2007).

Current use of precision technologies on Australian dairy farms primarily involves the use of animal monitoring technologies. Additional tools are currently in development, such as rumen sensors, inline milk quality sensors, automated weighing, remote video monitoring, satellite and ground-based pasture measurement, and targeted fertiliser application (García & Fulkerson 2005; Yule & Eastwood 2003). Further into the future the remote sensing of cow condition, GPS based cow tracking, and fenceless farms may be included in the suite of commercially available precision dairying technologies.

In terms of general ICT use on Australian dairy farms, an ABS (2006) study found 59 percent of Australian dairy farms used computers, an increase from 38 percent in 1998 (ABARE 2002), and 45 percent used the internet. Both computer and internet use were positively correlated with dairy farm size. Another study by Lubulwa and Shafron (2007) found approximately half of dairy farms used computers for farm and herd management, in particular for budgeting and financial purposes, maintenance of breeding records, and milk production recording. In a
review of the factors influencing use of farm information systems on NZ dairy farms, Alvarez and Nuthall (2006) found that individual user characteristics such as personality, experience, age, education, and goals were of primary importance.

In the wider agriculture industry, 32 percent of businesses used computers for farm record keeping and 48 percent used them for managing farm finances (ABS 2006). Bryant (1999) suggested that few South Australian farmers used sophisticated information technologies, however more recent data are not available. Slow adoption of ICT in the agricultural industry conflicts with uptake rates of Australian firms in general who have been rapid adopters of ICT in comparison to their international counterparts (Productivity Commission 2004). The dairy industry has rapidly adopted other technologies such as electric fencing and artificial insemination (Lubulwa & Shafron 2007). Potential reasons for slow uptake of ICT may be explained by Stubbs et al. (1998) who found that Australian farmers view computers as incompatible with their management style. Many farmers saw computers as time wasters; saw no reason to change from established methods; failed to see benefits which outweigh costs; and had difficulty determining the ICT to match their business (Stubbs et al. 1998). Lynch et al. (2000) cited research indicating farmers were frustrated by ICT requiring double-entry of data into separate software packages, or requiring collection of data not usually collected by the farmer. These features make ICT appear to involve too much effort for potential users.

2.4.3 Challenges for the future of precision farming

While little research has been conducted specifically on uptake of precision dairying, international studies have shown slow adoption rates of precision agriculture (PA) in the arable sector (Batte & Arnholt 2003; Daberkow & McBride 2003; Swinton & Lowenberg-DeBoer 2002). Farm size, farmer age, education level, computer literacy, and full-time farming status were identified as positive adoption drivers for PA in the USA (Khanna et al. 1999; Daberkow & McBride 2003), but overall Daberkow & McBride (2003) termed PA adoption ‘modest’, stating that up to 1998 only five percent of US arable farmers used an aspect of PA. This degree of uptake is mirrored in the Australian arable sector with only
around three percent of grain growers using some form of PA (Price 2004, in Robertson et al. 2007).

The lower than expected PA adoption in USA arable farming was attributed to “uncertainty in returns due to adoption, high fixed costs of investment and information acquisition, and lack of demonstrated effects of these technologies on yields, input-use, and environmental performance” (Khanna et al. 1999). A suggested reason for the low adoption of PA in Australia is the uncertain return on investment (Robertson et al. 2007). The advantages posed by the technology are often not immediately apparent and they require more management expertise along with an investment of time and money to realise (Bell 2002).

Harsh (2005) cites the significant ‘learning cost’ associated with use of IT on farms as being large enough to prevent their adoption. Cowan (2000) also identified several issues influencing the adoption of precision agriculture, which may also be applicable in the dairy industry:

- Farmers faced significant start-up costs;
- Primary capital and labour costs were associated with buying/renting equipment and developing baseline data;
- Private companies primarily conducted technical development of precision agriculture; and
- There was a need for PA crop specialists and people highly skilled in computers, technology, and data management.

According to Batte and Arnholt (2003), the relationships between components of complex farming systems need to be understood before there is more significant adoption. The technology needs to be simplified, decision rules improved, and data sources made more reliable and cost effective.

Lowenberg-DeBoer (2003) suggested improved PA uptake in Australia would occur through development of diagnostic tools, development of farm-level software for integration and analysis of data, support for PA farmer groups, and training for farm consultants, agronomists and crop advisors. These findings point to post-installation support as an important component in the successful use of these technologies.
Batte and Arnhold (2003) identify a lack of research on how farmers use PA tools for decision making, and on the benefits and costs of using PA technologies on individual farms. Many of the PA farmers studied by Robert and Iremonger (2003) were not properly using the data they had gathered, and they concluded that one of the primary areas where PA users require help is to ‘process, manage, and use efficiently all the data collected’. Additionally, a European survey found PA users had not yet used collected information to change farm management practices (Fountas et al. 2003). Spahr and Maltz (1997) identified the interpretation of sensor data and the determination of appropriate responses to individual cow information as major challenges for managers of robotic milking systems. Fountas et al. (2003) stated that ‘conversion of the gathered data into useful and valuable information for decision making and the interpretation of results still remain a challenge’.

Research has been conducted into the use of IT and management information systems to address dairy information needs (van Asseldonk et al. 1999b) and potential farm impacts of MIS adoption (Tomaszewski et al. 2000a & 2000b). Verstegen and Huirne (2001) conducted research into the relationship between farm management and value derived from MIS use in Dutch pig farming systems. However, there is little research specifically investigating the processes farmers employ to collect and use information in precision dairy systems.

2.5 The precision farming concept in summary

The first half of this chapter has provided an introduction to the precision farming concept, with specific reference to precision dairy systems. Key features of the concept are collection of fine-scale data, use of ICT, and enhanced management control. Despite positive perceptions of the potential of precision farming technologies held by members of the research and development community the extent of on-farm implementation has been low. There is a focus on the technical devices of precision farming, rather than adoption of a whole systems approach which recognises the role of farmers. In the next section the method and results of a scoping study are presented where issues facing the Australian precision dairying farming industry were investigated.
2.6 Australian precision dairy systems: A scoping study

2.6.1 Introduction

The limited knowledge concerning processes of precision dairy system implementation and the degree of information utilisation in precision systems, and potential barriers for future uptake, were discussed in the previous section. To address these knowledge gaps, a scoping study of farmers and service providers involved in precision farming was undertaken. Individual cow management systems were chosen as a case study because they represent the primary commercial example of precision dairy systems in Australia. Results from the scoping study were used to guide the design and direction of subsequent research in this project.

Research questions

The scoping study was designed to provide an insight into current ICT-based precision dairy farming practices. The following research questions were used to frame the study:

1. What processes underpin on-farm implementation of precision dairy systems?
2. What are the key issues for farmers learning to use PDF-ICT for decision making in their management practice?
3. How appropriate are learning support systems for farmers using PDF-ICT?
4. What are the issues for creation of innovative precision dairy systems at an industry level?

Research method

An inductive semi-structured interview method was suited to the explorative nature of the research questions. Participants were dairy farmers or service providers involved with the use of electronic identification (EID) based individual herd management systems. Recruitment of participants was undertaken using personal contacts and snowball sampling methods. Sampling stopped when no new themes were being uncovered, a stage Strauss and Corbin (1998) call ‘theoretical saturation’. The study was aimed at developing a knowledge base on the issues...
surrounding utilisation of individual cow management, as opposed to providing a representative picture of the Australian dairy industry.

Interviews were conducted at farmers’ properties, or service providers’ place of work, and were typically 60 to 90 minutes in length. Each interview was audio taped and later transcribed for thematic qualitative data analysis using QSR NVivo7™ software.

Table 2.3: Characteristics of 14 farmer interviewees (adapted from Nettle et al. 2006)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Case study coverage</th>
<th>(n)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The people</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Role on farm</td>
<td>Owner-operator</td>
<td>12</td>
</tr>
<tr>
<td>Manager</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Age (years)</td>
<td>&lt;35</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>35-45 years</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>&gt; 45 years</td>
<td>4</td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>14</td>
</tr>
<tr>
<td>Region</td>
<td>Gippsland</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Northern Victoria</td>
<td>7</td>
</tr>
<tr>
<td>Ownership</td>
<td>Family</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Partnership/corporate</td>
<td>2</td>
</tr>
<tr>
<td>Herd size (peak milked)</td>
<td>&lt; 300</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>300-600</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>&gt; 600</td>
<td>6</td>
</tr>
<tr>
<td>Milking shed</td>
<td>Herringbone</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Rotary</td>
<td>10</td>
</tr>
<tr>
<td>Herd testing</td>
<td>Monthly</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>2-monthly</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>4</td>
</tr>
<tr>
<td>EID system</td>
<td>NLIS eartag</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Collar</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Leg tag</td>
<td>2</td>
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<tr>
<td>Sensors</td>
<td>Milk meters</td>
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<tr>
<td></td>
<td>Conductivity</td>
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<td>Pedometers</td>
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<tr>
<td></td>
<td>Weighing</td>
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</tr>
<tr>
<td></td>
<td>None</td>
<td>3</td>
</tr>
<tr>
<td>Management tools</td>
<td>Individual feeding</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Auto draft</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>ACRs</td>
<td>8</td>
</tr>
<tr>
<td>Brand</td>
<td>Afikim</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Boumatic</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>OnFarm</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>DairyKing</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>DeLaval</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Ellimeter</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Jantech</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>WestfaliaSurge</td>
<td>1</td>
</tr>
</tbody>
</table>
Participants
In total 14 Victorian dairy farmers and 14 service providers, from Australia and Europe, were interviewed. Farmer and farm details are listed in Table 2.3 above. The service provider sample consisted of a dairy scientist, a dairy technology consultant, herd testing industry representatives (3), PDF-ICT designers (5), and PDF-ICT learning support technicians (4).

2.6.2 Significant themes
The significant themes arising from the scoping study surrounded the original goals and expectations of PDF-ICT users, the implementation and degree of utilisation, and factors associated with farmer learning in emerging precision dairy systems. These themes are discussed below and then contextualised in the emergent learning section. When quoted, participants are referred to via a pseudonym to protect their privacy.

Precision dairy systems – expectations and composition
The primary drivers for farmers installing PDF-ICT were based around efficiency goals in supplementary feeding and labour. The existence of the NLIS proved a driver for farmers looking to invest in entry level systems. Specific goals for the investment varied from farm to farm. Users wanted a tool to: aid in managing increased herd size, simplify the milking operation, or provide more timely information for feed decision making. Investment in ICT was usually undertaken when upgrading or building a new dairy shed, with one consultant estimating one in four new rotary dairy shed installations now includes some form of EID technology. All but one farmer interviewed installed their system during a major dairy shed upgrade or replacement.

Electronic identification based PDF-ICT systems are formed from a variety of hardware and software components. The system composition installed by an Australian dairy farmer exists on a continuum from very simple to highly complex, however installations generally fit into one of two main groups on this continuum depending on the sensor technology present (Table 2.4). Entry level systems, typically costing AU$15,000 to $30,000 use NLIS eartag EID and include no milk
yield or associated sensors. More advanced systems can cost over AU$100,000 (depending on dairy shed and herd size) and include data collection sensors controlled by management software with extensive herd management functionality. ICT use subsequently reflects composition, with entry level systems used as an operational aid while the data collection capacity of more advanced systems enables use in tactical decision-making.

Table 2.4: General system composition for Australian PDF-ICT systems

<table>
<thead>
<tr>
<th>PDF-ICT components</th>
<th>Entry level</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form of EID</td>
<td>NLIS Eartags</td>
<td>NLIS Eartags, Collar, Legtag</td>
</tr>
<tr>
<td>Data collection (sensors)</td>
<td>None</td>
<td>Milk weight/flow, Conductivity, Activity, Weight</td>
</tr>
<tr>
<td>Management software</td>
<td>Simple, limited functionality</td>
<td>Extensive functionality</td>
</tr>
<tr>
<td>Management aid</td>
<td>Individual feeding, automated drafting, automated teat spray, in-shed alerts, automated cup removers</td>
<td>Individual feeding, automated drafting, automated teat spray, in-shed alerts, automated cup removers</td>
</tr>
<tr>
<td>Common brands</td>
<td>Jantech, OnFarm*, Elimeter</td>
<td>Westfalia, DeLaval, Boumatic, Afikim</td>
</tr>
</tbody>
</table>

* This company now operates under Livestock Improvement Corporation (NZ)

Entry level systems are more easily retrofitted into old dairy sheds and, while advanced systems can also be retrofitted, configuring sensors and wiring into an existing layout can prove problematic. Most of those interviewed described technical problems, for example EID inaccuracy, in the months after installation. The need to fine-tune signal strength in EID readers was one of the main causes but respondents also identified problems using technology not initially designed for Australian dairy systems, and insufficiently beta-tested technology. This could be a reflection of the greater complexity in Australian dairy systems compared to the European dairy systems for which this technology was originally designed. Technical problems affected user confidence in both the system and the data collected resulting in use of risk management strategies such as udder paint, freeze brands, and manual information recording procedures.
Implementation and utilisation of precision dairy systems

Farmers used PDF-ICT for strategic, tactical, and operational management tasks, but the primary form of use was for operational (daily) tasks (Table 2.5). Operational usage was based around streamlining systems either in the dairy shed or with record keeping. Tactical usage involved more proactive management and prediction of future events or trends.

Table 2.5: Precision dairy practice across management levels

<table>
<thead>
<tr>
<th>Management level</th>
<th>Examples of precision dairy practice</th>
</tr>
</thead>
</table>
| Operational      | - Management by exception *(e.g. low milk yield, activity)*  
|                  | - Risk management *(e.g. alerts on withhold cows)*  
|                  | - Record keeping *(e.g. breeding details, quality assurance)* |
| Tactical         | - Proactive management strategies *(e.g. predicted calving, predicted heat)*  
|                  | - Intra-herd comparison *(e.g. breaking herd into virtual groups)* |
| Strategic        | - Long term decision making and assessing achievement of goals *(e.g. response to grain, achievement of cow performance targets, labour efficiency)* |

The tangible benefits identified by the interviewees (for example see Farmer 8 below) were primarily in the area of operational management: labour savings, timelier decision making, and general efficiency gains. Less tangible benefits included: making milking ‘more interesting’, and lower overall stress levels. Monetary savings from use of the technology tended to be masked by expenditure or resource use being reallocated rather than reduced. This reallocation effect occurred particularly with labour where increased efficiency did not necessarily lead to lower labour costs, rather staff had more time to spend on other farming tasks. Another example identified in the study was in the change from a set feeding rate applied to all cows, to individual feeding where total grain fed per annum remained static but allocation of the grain was targeted at increasing the milk:grain ratio. In larger herds daily individual cow data provided the owner or manager with more autonomy, allowing them to review key performance and health indicators without being present at milking. The form of benefits related by the farmers interviewed in this study were similar to those identified by Jago and Calder (2007). They quoted mostly labour saving benefits associated with
operational tasks along with lowered stress levels, more flexible working arrangements, and timeliness of decision making.

‘There are probably a lot of benefits, some that you don’t even think about. You start taking a few things for granted I think, but I’m sure the benefits are in large herd management, if you can keep records, … So you’re not worried about the book getting burnt or it falling out of your pocket in the channel or losing it altogether because its all there in the program… it helps to simplify it, but if they want to know if there’s a cow been through this morning they can just key her number in and they know what time she went through the platform and that sort of thing, they’ll know how much milk she’s given as well. And it’s all that sort of stuff. They sound, like they can sound too simple, even the day to day little things that are benefits.’ (Farmer 8, 2005)

Some retailers interviewed suggested the concept of ‘power users’, meaning those farmers who use the technology and data at an advanced level. These users tend to have the ability to make their own reports, allocate regular time at the computer, make extensive and variable use of alerts throughout the season, and use batch entries. They also exhibit the greatest linkage of ICT into their farm management process, starting with regular and dedicated data entry through to consulting the ICT system when making decisions.

Interviewees expressed different paradigms in regard to ICT importance in their farming system. One perspective was that ICT was just another tool in their management toolbox which sat external to their management process. An alternative perspective saw utilisation of the ICT technology and data as integral to management practice, for example where farmers established a daily routine of reviewing updated data after the morning milking. Integration relied upon adaptation of daily routines to incorporate the ICT system, as expressed by one farmer interviewed:

‘The hard bit was to fit it into a routine … because it’s not a technology that I had actually been in contact with, its requirements had to be sort
of fitted into the routine of the day, if the cow’s calving to actually put it in, you know once that routine was established it was a lot easier.’
(Farmer 9, 2005)

Key factors in the level of integration were the time spent at the computer and degree of structured data entry. There was a belief amongst participants that too much time could be spent on the computer, at the expense of other tasks on the farm, and time in the office was often not prioritised. In some cases computer-related tasks involved basic yet time-consuming data entry. Such tasks could easily be delegated to other farm staff thereby allowing the owner/manager to prioritise computer interaction to higher level planning tasks, constituting a more efficient use of management time.

On-farm adaptation of precision dairy systems occurred in two forms: firstly farmers adapted the material technology in order for it to work on their farms, and secondly they adapted their management around the technology to incorporate the new information sources in decision-making. Existence of the first type of adaptation, technical adaptation, indicated that each PDF-ICT system required some form of effort to imbed into the surrounding infrastructure and technology. An example of this was re-positioning EID readers in order to fit specific milking platform dimensions. Existence of the second form of adaptation, management adaptation, highlighted the importance of the farmer in a precision farming system. After the material technology was installed, farmers needed to adapt around the new technology and the information it produced. An example is farmers adapting to using cow activity graphs to assess oestrus rather than using visual assessment methods. While the technical and management adaptation associated with PDF-ICT use were identified in the scoping study, more information is required to understand these processes in greater detail.

In the post-installation adaptation process, there was evidence of unrealised potential in PDF-ICT system use, as expressed by Farmers 1 and 7 below. The reasons for not using particular functions included perceived lack of benefits, time constraints, technical problems, and low confidence with use of ICT. Further
research is required to understand the farm-specific drivers or barriers impacting on utilisation of precision technologies.

‘Essentially that will do a lot more than what we’re doing with it, it’ll do automatic draft out, it’ll automatically relate feed to, feed dump to cows, but we don’t do any of that.’ (Farmer 1, 2005)

‘I had graduation this year and [PDF-ICT retailer] spoke, the head manager, they reckon that everyone that has their full system in only uses 15 percent of the technology involved in it. Which I probably would not disagree with.’ Farmer 7, 2005)

Precision farming systems, such as those studied in the scoping phase, are often installed to streamline operational management. However, there were several examples of where the benefits of streamlined management were not fully achieved. One example was incompatibility between software, such as two software programs performing slightly different management functions between which data could not be transferred. Another example was where different technology components could not be operated by one software program, for instance where a farmer selected cows to draft in one system then printed this list to input into a second system which controlled the auto-drafting. Such issues, often due to proprietary restrictions, impact the goal of using precision farming technology to increase management efficiency.

**Learning to use the new system**

Key learning issues for the ICT users interviewed were the initial learning curve, promotion of ongoing learning, training of staff, and defining user roles.

The post-installation period is where the learning curve is steepest for users yet several factors can distract learning in the first few months of operation. These factors include the occurrence of faults as previously mentioned, a focus on adapting to milking in a new dairy shed, and the availability of learning support. ICT system faults impacted learning by restricting overall system useability and also denting user confidence in system accuracy. Because the technology is often
installed during a shed upgrade or rebuild and commissioning is timed to coincide with calving, adapting milking routines and becoming comfortable in the new shed can take priority over learning ICT use. Learning to explore the potential of the ICT system is delayed because as one farmer commented they ‘just tried to survive the first months with the new system’.

Most respondents received some training from the technology retailer at the time of installation, ranging from one to four hours. Often it is a case of too much information too soon for new users, with trainers explaining potential system usage and the particular computer procedures required. Farmers had difficulty contextualising the system’s capabilities, and were sometimes overwhelmed in attempting to memorise computer commands. It appeared that it was not until after several months of using the system that farmers began to understand what they wanted to achieve with it. It is at this stage that additional training was most required.

‘That’s the sort of stuff, the sort of sitting down when you’re not aware of how the system works, you’ve sort of got the basics of what happens but until you have that, it was sort of 12 months before we started putting the hot keys and stuff like that, until we understood how it actually worked’ (Farmer 4, 2005)

Training involved on-farm visits, phone support, remote computer access, user groups and manuals. More advanced systems were associated with a variety of training methods. Small market size, particularly amongst the advanced systems, negatively impacted on the ability of retailers to provide extensive support structures. On-farm visits were infrequent, as were user groups. In comparison to this the farm management software ‘MISTRO’ (Gippsland Herd Improvement) is popular within Victoria and is supported by user training days and an internet forum. Whereas advanced ICT user groups attracted around five participants, one MISTRO group training day involved 15 users.

As would be expected, the time taken for farmers to feel competent in using ICT depended on the system complexity, with farmers coming to grips with simpler
systems more quickly than those using complex systems. Achieving competency in advanced systems could take one to two years. At this point farmers appeared to become comfortable with their level of use, and few carried on the learning process to achieve advanced use (further discussed in regard to the ‘utilisation gap’ in section 2.5.3). The general pattern of learning involved an early discovery phase, where reports were constructed and data entry was relatively unsophisticated. During this phase users also developed a certain level of trust in the PDF-ICT system based on factors such as accuracy and reliability. After the discovery phase, the farmers consolidated their use to the features they found most beneficial in their own management practice. For example some users actually reduced the number of regular reports used based on an informal benefit-cost decision, where the time cost of reviewing reports was weighed against the benefits for management efficiency and accuracy. In this consolidation phase users also became more sophisticated with use of features such as batch entry and automation, as they learnt new functionality. Further research is required to examine this early learning phase, and to determine the factors which influence the learning process of precision dairy farmers.

Structured training in more advanced systems was run from the company head office, while local agents were used for trouble shooting. Farmers felt most connected with their local dealer, and their impression of the dealer’s after sales support was often a key determinant in the choice between different products. However ICT skills were low amongst most dealers and they were ill-equipped to provide support on advanced software queries.

The interaction of farm staff with the PDF-ICT was an important factor on larger farms. On these farms staff may be required to use the systems on a daily basis while milking, something they viewed in both a positive and negative light. While published ICT adoption research identified an inverse correlation between a users age and the use of precision farming tools (Khanna et al. 1999; Daberkow & McBride 2003) this was not always the case for the farms in this study. Personal attitudes tended to be more important, as described by Farmer 8 below.
‘If you’ve got the younger people it does help with the computer, but then there are some young people about in a lower order of labour that aren’t, you know they’re not really that computer literate either, and you’d be concerned about letting them loose on the thing anyway. So you’ve got to find that line of, to find the people who want the responsibility and want to work it and learn to understand it.’ (Farmer 8, 2005)

Farm managers interviewed described the staff-ICT relationship in differing terms. Some saw ICT as important in covering for low skill levels of staff and stated they had more faith that important operational tasks would be performed because the computer system was installed. In contrast, others stated that the system was not installed to replace staff and that skilled and adaptable staff were as important with ICT as they were beforehand. Respondents were divided over whether having new technology in the dairy shed made it easier to attract workers with some expressing a concern that computers actually intimidated some potential employees and that often workers have low computer literacy. There was also variation between different PDF-ICT products in respect to their ease of use for staff, and therefore semi-skilled employees were able to learn basic milking functions more easily in certain systems. Staff with prior ICT skills found it easier to learn to use PDF-ICT systems and this scoping study highlighted the need for industry-wide capacity building in terms of the ICT skills of dairy farm employees.

There was also a divergence in the way staff were trained in the use of ICT. In general retailers viewed staff training to be the responsibility of the farm owner or manager and therefore targeted training at them. They believed that the key decision maker would pass their ICT knowledge to staff however staff training was often placed lower on a priority list than other farm tasks. One farmer summed up staff training by saying:

‘We have been trying to teach them but the way it is... there’s a reluctance for them to do it, just because I don’t think that the people that we’ve got at the moment are very computer literate so there’s that scared factor of the computer anyway...if one of us is there they’re
quite happy for someone else to do it, they’ll go and do something else. And we probably don’t enforce to do it because we’re just trying to finish up get out of there.’ (Farmer 4, 2005)

The use of individual monitoring allowed primary decision makers to remove themselves from the routine of milking and focus on tactical management tasks. This placed a responsibility on milking staff to be aware of changes in stock health and to possess a level of ICT proficiency to complete daily herd management tasks. It also required managers to have confidence in the aptitude of both staff and technology to maintain health and production monitoring standards.

On large farms, efficient integration of ICT systems into farm management depends on appropriate allocation of ICT responsibilities. One person, usually the manager, undertook most ICT functions and in several cases the farmer interviewed commented that staff only used the computer system for the most basic data entry, such as entering alarms for cows with health problems or noting joining dates. Lack of trust in the computer competency of staff, and a belief that staff do not have the same attention to detail as a farm owner, were barriers to greater delegation of responsibility. One farmer discussed the options when allocating a data entry role:

‘One is have someone that is responsible for the computer inputting and I mean many a farmers wife does that, but we don’t have the wives involved (on this farm)… the other thing we did find too was that if you did have somebody totally dedicated to doing those sorts of tasks was that if they were not there or were sick or whatever you’re in a bigger conundrum. So we’ve certainly tried to train more than, or have more than one of the staff ‘au fait’ with what happens.’ (Farmer 8, 2005)

The comment above also highlights a gender theme that emerged from this study. In several cases the main person responsible for database management (data entry and basic data manipulation) was either a farming wife or female staff member. This observation aligns with findings by Bryant (1999) who identified a gender division of labour in respect to use of software. In Bryant’s study women were commonly responsible for bookwork, with men responsible for physical
labour and management. Further research is required to ascertain the influence of gender roles in precision dairy systems.

PDF-ICT service providers are not the only people with whom interaction is important for farmers learning to use ICT. Nutritionists in particular often play a role, particularly in setting up automated feed tables. In the pre-sale process farmers often sourced advice from existing technology users on other farms, placing a lot of weight on the experience and opinions of these users.

Industry issues

Australian versus multinational supported precision dairy systems

PDF-ICT systems are marketed by both Australian and multinational companies and the importance of system origin was discussed by respondents who highlighted issues of system applicability, adaptability, support structures, and compatibility between different systems. ICT originally designed for European or American dairy systems was viewed as having potentially less applicability for use in Australian pasture based systems. The use of non-Australian jargon, for example the use of the American term ‘parlor’, increased this perception. Latent capacity in the software stemmed from a higher overall level of functionality compared to entry level systems. International PDF-ICT generally fits into the ‘advanced’ category discussed previously and is more comprehensive, designed to cover a wide range of uses in dairy systems ranging from full feedlot to pasture based, resulting in unsuitable functions in any given system.

Advanced PDF-ICT systems were seen to be more adaptable and powerful than entry level systems but this posed a double-edged sword in terms of learning. While the entry level systems, focussed on specific management tasks such as drafting and individual feeding, were easier to learn due to limited ‘depth’ in functionality, users commented on their ‘locked-in’ nature and lack of adaptability to farm specific requirements.

PDF-ICT products differed in terms of training and support structures. Large multinational companies generally had comprehensive technician networks in
Victoria whereas the smaller local products were supported by one or two technicians responsible for Australasia. In some instances this resulted in longer wait times for on-farm support of the local products. Stable support structures were important for users and they expressed concerns that smaller retailers were more likely to exit the industry resulting in unsupported products. These perceptions led to reluctance from some interviewees to invest in a locally produced product. However no respondent actually experienced collapse of PDF-ICT support.

Compatibility between different PDF-ICT systems, and between individual components, was a major issue for respondents. One example frequently quoted was the inability to freely transfer data between herd management software and herd testing software, a problem particularly prevalent in respect to advanced multinational PDF-ICT. Some systems required special software ‘links’ to be written to facilitate data transfer, however often these only worked one-way. Proprietary controls also prevented some users from adding components from other companies, such as weigh scales, into their PDF-ICT system. There appears to be a lack of relevant industry standards enabling systems to transcend national herd recording and data transfer structures. For example, although international origin PDF-ICT systems are designed with a standard data transfer relevant to their primary market, the same protocol is not used in Australia. This is therefore an issue to be addressed at the industry-level, rather than by individual developers themselves.

On farm data collection and the dairy industry
Increased on farm data collection and use of PDF-ICT pose both opportunities and threats to the wider dairy industry. Collation of farm data into an industry-level database, as occurs currently in the Australian dairy herd improvement scheme (ADHIS), presents an opportunity for benchmarking of key performance and health indicators. Collation in real-time of milk yield data in particular would be beneficial for milk companies wishing to improve modelling of future milk volumes. Interviewees highlighted privacy concerns of farmers as a potential barrier to such data collation in addition to lack of incentives for farmers to sign up for, and allocate time to, providing their data to a central database.
The national herd improvement scheme (ADHIS), and the sire proving scheme it supports, could be either winners or losers from increased on farm data collection from PDF-ICT. If, as outlined above, relevant data were automatically uploaded to an industry database the result could be a timelier, more reliable, and more extensive herd recording scheme. However if farmers internalised the data this could threaten ADHIS which is already under pressure from reduced subscriber numbers (ADHIS 2005). Such an impact was indicated by service providers interviewed, and exhibited by some farmer respondents who had reduced herd testing frequency or cancelled it outright due to use of yield data from milk meter, in-line milk conductivity data, and factory somatic cell count (SCC) readings in decision making. Currently, the need for regular SCC measurement for mastitis identification is the primary reason farmers continue herd testing however commercial release of in-line SCC sensors would remove this herd testing incentive.

Industry role for learning support in precision dairy systems

Respondents were unsure whether there was a role for industry organisations in PDF-ICT training. Some thought more work could possibly be done to improve computer literacy amongst farmers but, generally, training was seen to be the responsibility of the relevant retailer. A need exists for capacity building of ICT skills amongst dairy farm employees. With a higher skill base, employees would be positioned to accept greater responsibility with use of PDF-ICT, aiding the efficiency of precision dairy systems.

2.6.3 Emergent learning

A continuum of utilisation potential

PDF-ICT systems are normally designed with greater functionality than a specific individual user requires, often due to the desire to cater for a wide range of possible use and to enable a single product to appeal to the varied needs of the market. This is common in everyday technology such as washing machines with multiple settings or mobile phones with games, internet, and camera functions. Latent potential is therefore created, particularly in advanced PDF-ICT, where a
proportion of the systems functionality is irrelevant to a particular user, as outlined by Farmer 3 below. The degree of functionality which is irrelevant to a particular user is primarily dependant on their specific goals for the system.

‘We had the bloke out here that developed the program four weeks ago and the stuff that he was getting off the computer was just well I mean when would you ever use that?’ (Farmer 3, 2005)

The PDF-ICT functionality feasibly useful in a specific farm enterprise is termed ‘farm-specific potential use’. In the scoping study, respondents highlighted actual usage as being generally lower than their potential utilisation. This scenario is presented as a PDF-ICT utilisation continuum in Figure 2.2 below, where the difference between ‘actual use’ and ‘farm-specific potential use’ is identified as the ‘gap in potential utilisation’.

![Figure 2.2: Schematic of a PDF-ICT utilisation continuum for an individual user](image)

Does the utilisation gap represent a lost opportunity to PDF-ICT users or is it a case of farmers prioritising their interaction with ICT and making a conscious decision to limit time at the computer? It is difficult to provide a definitive answer based on the scoping study however some insights were gained. PDF-ICT tends to be used primarily for operational management rather than tactical or strategic. For example milk yields are used to aid decisions on drying off dates and cow culling but little advanced data analysis is undertaken to determine changes in key indicators such as grain:milk ratios or milk income over feed costs. Lack of data analysis to identify and interpret production or health trends therefore accounts for
some of the non-utilised PDF-ICT functionality. Farmers are possibly held back by a lack of awareness around what can be achieved using the technology.

Limiting use of advanced PDF-ICT to operational management means that potential benefits from improved tactical and strategic management processes are not realised. Sankey (2002) highlighted enhanced benefits of longer-term management by suggesting there is a ten-fold higher economic return per hour spent on tactical management compared to operational management. While streamlining operational herd management is an obvious strength of PDF-ICT, there are substantial opportunities for use of PDF-ICT and the data it collects, to improve efficiency of the whole farm system.

Stubbs et al. (1998) found that the majority of farmers were from a non-computer generation and many failed to see the benefits of ICT. Farmers in the scoping study, probably representing more computer literate farmers, did not possess such a negative view of ICT but did acknowledge that ‘you could spend too much time on the computer’. They appeared to perform a tacit benefit:cost analysis where the cost of investing extra time at the computer was weighted against perceived benefits. At a certain level of time investment, respondents prioritised other farm management tasks higher than computer-based activities. The ICT time commitment is continually negotiated, with some users initially using many ICT functions and then refining their use to key reports over the first months of learning.

**Adaptation as the key to innovative precision dairy systems**

A key factor in achieving benefits from ICT is the ability to adapt the system into farm management routines. Individual attitudes, of both primary users and staff, to the new system are important in this adaptation process. A potential issue for farmers is the adaptation from a highly tacit management style to one which mixes both tacit and explicit knowledge. The challenges of this process of knowledge adaptation were not fully explored in the scoping study and require further research.
Computerised herd management systems can be used to take responsibility for the ‘lower’ end of the data-information-knowledge-wisdom hierarchy by storing individual data, and using pre-set filters and parameters to collate, group, and present key information. This should provide farmers more time to concentrate on tactical and strategic management which align with the knowledge-wisdom phases of the knowledge hierarchy. An integral part of innovative precision dairy systems is the ability of ICT to assume management of these lower-end aspects of farm decision-making, providing farmers time to appraise the farming system from a more holistic viewpoint.

The learning challenge in emerging precision dairy systems
Learning to use precision dairy systems can be broken into the three phases of early learning, learning consolidation, and advanced learning. The learning process can occur over a season or more as users relate PDF-ICT functionality to phases of cow lactation, such as calving, mating, and drying off. ICT system learning is a continual process and requires time to develop, as identified by van Asseldonk et al. (1999a). This has implications for the delivery timeline of learning support by retailers. Where most training effort was targeted at the months after installation, farmers in fact require training to span one or two seasons. Training approaches should also focus on specific learning characteristics of the three learning phases as different types of skills and knowledge need to be transferred during the early learning phase compared to the advanced learning stage.

Currently precision dairy farmers are grasping the concepts and functions of PDF-ICT in the early learning phase, and then consolidating this knowledge by applying it to match the specific requirements of their farming enterprise. However, few users appear to be taking the next step to advanced learning, which is possibly one reason for the gap in potential utilisation discussed earlier. This observation forms the basis for the longitudinal research which was subsequently conducted in the overall study (Chapter 4 and 5).
2.7 Conclusion

In this chapter, the concept of precision farming has been examined, including its role in information gathering and its fit with dairy farmer decision making. A scoping study carried out with precision farmers and relevant industry personnel identified the key emergent themes of: an information utilisation gap, issues for management adaptation, and the learning challenge faced by new precision technology users. Findings from the scoping study are summarised below in respect to the original research questions:

1. **What processes underpin on-farm implementation of precision dairy systems?**
   Farmers implementing precision dairy systems face a steep early learning curve. They undertake both technological and management adaptation processes in order to integrate precision systems into their specific management practice. Currently these adaptation processes appear to create a level of PDF-ICT utilisation which is less than individual users could achieve.

2. **What are the key issues for farmers learning to use PDF-ICT for decision making in their management practice?**
   When learning to use PDF-ICT farmers go through three phases of learning: an early learning phase, a consolidation phase, and an advanced learning phase. To streamline learning, farmers need to develop an understanding of which functions of PDF-ICT are applicable to their particular goals and management practice.

3. **How appropriate are learning support systems for farmers using PDF-ICT?**
   Current learning support systems for precision dairy farmers appear highly focussed on the early learning phase. As a consequence a limited number of farmers are exhibiting advanced use of PDF-ICT systems. Learning support systems need to be tailored to the three phases of PDF-ICT learning.

4. **What are the issues for creation of innovative precision dairy systems at an industry level?**
   At the industry level, more focus is required on building ICT skill capacity within farmers and their employees. Additionally, dairy industry organisations need to
take a lead role in enabling streamlined functionality and data transfer between PDF-ICT products to enable innovation in precision dairy systems.

The emergent themes of learning and adaptation flow through the following chapters and drive the development of a six farm case study. In Chapter 3 the development of a theoretical framework applicable to these emergent themes is discussed, and a research method to further investigate the themes is described. Chapters 4 and 5 present the subsequent research findings in the form of an individual and cross-case analysis.
3. Theoretical basis and research design

3.1 Introduction

The findings of the scoping study in Chapter 2 focussed on the challenges of learning and management adaptation as key features of ICT use on dairy farms. In 2005 further research was initiated to examine these factors in greater detail. The research design, outlined in section 3.3, used an inductive approach within exploratory case studies of six Australian dairy farms. In line with its inductive and exploratory nature the case studies were guided by general research questions rather than specific hypotheses. Findings from the case study were situated within existing theory. However, in order to prepare the reader for the interpretation of case study results, and the subsequent cross case analysis, the conceptual framework is presented in this chapter prior to the case study results in Chapters 4 and 5.

The adoption of precision dairying practice by farmers in this study involved significant issues around the processes of adaptation and learning. Therefore this chapter is focussed on theoretical perspectives of learning, both at the individual and organisational level. From a farmer’s perspective learning is key to a continuous improvement in performance, through adapting best practice (Parker 1999). Factors that influence the learning process are discussed in this chapter, initially through a description and critique of Kolb’s (1984) experiential learning theory. Case study dairy farms also exhibited features of organisational learning and therefore relevant theories are reviewed. This review of individual and
organisational learning forms the basis for critical analysis of the case study findings.

3.2 Theoretical framework development

3.2.1 Individual learning

Theoretical approaches to learning have focussed on both the individual and organisational scale. Individual learning theory is based around the concept that everyone approaches learning differently and that the outcome is not just due to knowledge or experience but also factors such as beliefs, goals, and societal expectations.

Kolb’s experiential learning theory

Learning is described by Kolb (1984) as the process whereby knowledge is transformed by experience. To describe this process Kolb (1984) developed an experiential learning theory (ELT) that depicts learning via four learning styles positioned on two axes (Figure 3.1). On the first axis individuals grasp experience via concrete experiencing of events at one pole and abstract conceptualisation at the other. Concrete (tangible) experience is grasped through apprehension, while comprehension involves conceptual interpretation (thinking). Kolb’s second axis concerns the transformation or processing of information collected through experience. Reflective observation and active experimentation form the two poles of this axis.

An example of this learning process could be seen where a farmer decides to feed silage to cows in a sacrifice paddock, resulting in a rise in mastitis occurrence in the herd (concrete experience). The farmer then reflects on the cause of the mastitis (reflective observation) and determines the wet and muddy conditions in the sacrifice paddock to be the cause (abstract conceptualisation). In response to this conceptual model the farmer decides to feed silage out on a different paddock and to observe the impact on mastitis occurrence (active experimentation). The learning cycle continues as the farmer experiences the results of the changed strategy.
Figure 3.1: An experiential learning cycle (based on Kolb 1984)

The learning-style inventory (LSI) derived from Kolb’s model was initially developed to assess the learning attributes of students but it has been widely used in disciplines such as management and computer science. The LSI, described by Kolb (2007) as ‘an experience in understanding how you learn’, divides the experiential learning model into four quadrants indicative of an individual’s learning preference. The four quadrants are: active-abstract (converger); active-concrete (accommodator); reflective-abstract (assimilator); and reflective-concrete (diverger) (Figure 3.1). Individuals learn using a combination of all four styles across the two dimensions, and it is the relative emphasis on each style that distinguishes between learners. The highest form of learning involves combined use of all four styles, but in general people are more dominant in one particular style. General characteristics of the four styles are listed in Table 3.1.
Table 3.1: Characteristics of learning styles (Jagdev et al. 2004)

<table>
<thead>
<tr>
<th>Learning style</th>
<th>A person with this style excels at:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Converger</td>
<td>Problem solving, decision making, and practical application of ideas. Able to focus on specific problems and prefer to deal with things rather than people.</td>
</tr>
<tr>
<td>Accommodator</td>
<td>Solving problems in an intuitive trial-and-error manner, adapting to changing circumstances. Learns best from self-directed learning, computer-based training, learning through practical experience</td>
</tr>
<tr>
<td>Assimilator</td>
<td>Building conceptual models, organising information, testing theories and ideas. Likes information presented in organised and strategic sequence</td>
</tr>
<tr>
<td>Diverger</td>
<td>Using their imagination, information gathering, and awareness of hidden implications in ambiguous situations. Prefers brainstorming; tasks and activities involving reflection</td>
</tr>
</tbody>
</table>

LSI assessments can be influenced by external factors, for example an individual may answer the questions differently depending on the learning issue they are currently focussed on. Learning styles remain relatively stable over time however, because it is shaped by experience, a persons learning style may change as a result of new experience gained. Kolb (2007) suggested that the LSI should not be used for arbitrary measurement but rather as a tool for an individual’s self development. This is achieved through identification of the learning styles that need development, for example assimilator, and using activities that focus an individual’s development in this area. In the farmer case studies that follow this chapter, the learning styles inventory was used as a tool for stimulating discussion with each participant around the theme of learning support.

Experiential learning theory has been applied to the ICT domain. Cross et al. (1994) state that people with strong reflective observation and abstract conceptualisation preferences (assimilators) may align best with use of computerised record systems and decision support systems. In comparison accommodators, who prefer concrete experiences and active experimentation, may not accrue similar benefits from information systems.

Kolb’s model is still a central theory in experiential learning, and is unique in integrating multiple epistemologies into a formal theory of learning (Kayes 2002). But it has also been the subject of significant critical review. Construct validity and reliability of the LSI measure has been questioned (Towler & Dipboye 2003). Jarvis (1987) suggested that it lacks emphasis on the role of reflection in learning and that there is a limited experimental base to support the theory. Learning is
perceived by Kolb to occur in stages whereas other authors suggest that such processes can occur in differing orders, simultaneously, or in a non orderly fashion (Kayes 2002). Also, according to Kayes (2002), the ELT ‘decontextualises’ the learning process and focuses on the individual at the expense of psychodynamic, social, and institutional learning influences. By focussing on experiential influences, it addresses learning as a past activity, rather than constantly evolving. Critics of the ELT identify the need for greater integration of reflective practice in the learning theory (Kayes 2002) and call for a stronger emphasis on critical reflection as opposed to reflective observation. March and Olsen (1975) also comment that there are limitations to learning by experience and that people choose the decision with highest return when they have limited time to invest in learning. Also exact behavioural motives and intentions are often only discovered after the fact.

In seeking to add to the experiential learning theory, Kayes (2002) suggested a conceptual difference between personal and social knowledge. In this scenario experience and reflection are aligned with personal, or tacit, knowledge. Abstraction and action are within the social (explicit) knowledge domain. While knowledge can move between the two forms it is not always a clean transformation with something invariably lost in the process. This is addressed by Nonaka (1994), and aspects of social knowledge are considered further in the following section.

**3.2.2 Organisational learning**

At the core of organisational learning is the process whereby an organisation adapts to its environment by detecting and correcting errors (Argyris & Schön 1978). Cyclical development of knowledge and understanding through learning is vital in this adaptation process. Dairy farm businesses exhibit organisational learning characteristics, for example when faced with a mastitis outbreak the farmer calls upon a network of people including veterinarians, consultants, and other farmers to find the cause and a solution. Even within smaller owner-operator enterprises individual farmers do not exist in learning isolation as there are often family, workers, neighbours, and other off-farm sources to learn with and from. In this way the farm as a learning organisation exists beyond the farm gate, with networks both tangible and intangible into the farming industry.
In this section organisational learning theory is critiqued in order to develop a theoretical framework with which to analyse the six farm case study findings. Nonaka (1994) described the concept of tacit and explicit knowledge, along with a process of alternating knowledge between these two knowledge forms. He also identified a need for reflection during the conversion of tacit to explicit knowledge, a concept explored through Argyris and Schön’s (1978) theory of the reflective practitioner. The role of reflection in reducing equivocality within an information environment is then explored using the model of organising proposed by Weick (1969). At the heart of this theory is communication cycles between people in loosely coupled systems where information flows and learning occurs between groups that are informally linked. Lave and Wenger (1991) expanded on this idea with their community of practice theory. Communities of practice are reviewed at the end of section 3.2.2 as a theoretical framework within which to view the development of precision dairy systems.

**Organisational knowledge creation**

Nonaka (1994) criticised the ‘input-process-output’ information processing paradigm of organisational theory, calling it a ‘passive and static view of the organisation’. Organisations, according to Nonaka, should not only process information and knowledge but also create it. In his theory of organisation knowledge creation, Nonaka focuses on the idea that knowledge is created via a constant interaction between the tacit and explicit knowledge forms. He identified four directions in which this interaction may occur: tacit to tacit, tacit to explicit, explicit to tacit, and explicit to explicit (Table 3.2). The transfer of tacit knowledge between people, termed ‘socialisation’ by Nonaka, involves mechanisms such as observation, imitation, and practice. Converting explicit to tacit knowledge (internalisation) is similar to learning as traditionally perceived, where documented knowledge is stored by the learner as memory. Social processes or the act of sorting and reconfiguring information (like a computer) are involved in the transfer of explicit to explicit knowledge. While the concepts of socialisation, internalisation, and combination bear similarities to organisational theory, Nonaka sees externalisation, the transfer of tacit to explicit knowledge, as an under-developed component of organisational theory.
Table 3.2: Matrix of knowledge creation modes (Nonaka 1994)

<table>
<thead>
<tr>
<th>From: Tacit knowledge</th>
<th>To: Tacit knowledge</th>
<th>Explicit knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socialisation</td>
<td>Externalisation</td>
<td></td>
</tr>
<tr>
<td>Internalisation</td>
<td>Combination</td>
<td></td>
</tr>
</tbody>
</table>

Externalisation is a relevant process for farmers dealing with knowledge transfer, in particular those using ICT where management knowledge is highly tacit-based. The interaction between a trainer and farmer can involve conversion of a trainer’s tacit ICT knowledge into an explicit form for farmers to receive, in addition to farmer’s themselves converting their tacit dairy farm management knowledge into an explicit form to guide the content of ICT training. According to Nonaka, when in a team or ‘field of interaction’, people share explicit knowledge until it is learnt and converted into tacit form. Parallels can be drawn between this internalisation process and practice observed within dairy farm management, and pasture management in particular. As discussed in Chapter 2 dairy farmers will often only use objective (explicit) pasture measurement tools for a short period of time then discard them and adopt a tacit-based approach when they are comfortable they have trained themselves or their eye.

**Importance of reflection in learning**

One of the main critiques of Kolb’s experiential learning approach was the lack of emphasis on reflection (Jarvis 1987). Nonaka (1994) also identified the need for reflection during the evolution of tacit knowledge to the explicit form. Reflecting during experiential learning is an important method of rationalising the meaning of the experience and inherently involves a social network. This concept was embodied in Schön’s (1983) ‘reflective practitioner’ where continuous learning was achieved through reflecting on experiences, rather than only learning after a problem was detected.
Reflection is especially important where people’s actions differ from their initial intentions. Argyris and Schön (1978) collaborated to develop organisational learning theory centred on how people decide to act in a situation. They suggest that people have mental maps guiding their actions, termed theories-in-use, which can differ from how they say they will act (espoused theories). The theory-in-use approach can be used to re-examine the decision making process which Argyris and Schön (1978) divide into three phases (Figure 3.2). Initially people establish governing variables within which they are comfortable, they then use action strategies which involve the actions implemented to maintain governing variables, and then the consequences of these strategies are assessed.

![Figure 3.2: A model of the processes underlying theory-in-use](image)

If a desired consequence occurs then the approach, or theory-in-use, is deemed a success. However, if the end result is unexpected people can take one of two potential reactions, either (a) devise a different action strategy that does not conflict with the governing variables or (b) reflect on the governing variables, existing norms themselves. Argyris and Schön (1978) term these two reactions single-loop learning and double-loop learning respectively, with double-loop learners also seeking to publicly test their theory-in-use. Levitt and March (1988) describe double-loop learning as the redefinition of events, and Nonaka (1994) views it as the questioning and reconstruction of existing perspectives. Double-loop learning is a powerful and flexible learning approach because the use of reflection enables people to discover new approaches to problem solving, cultivate innovation, and respond to a rapidly changing environment.
In focusing on people’s theories-in-use, Argyris (in Smith 2001) identified Model I and Model II learners. People exhibiting the Model I style are predominantly defensive in their learning, using a process termed defensive reasoning, acting in the fear of failure and with the aim of preventing embarrassment or threat (Smith 2001). Such learners do not accurately expose the motivations behind their actions to avoid being shown to be incorrect or incompetent. This is essentially a closed loop because the theories go unchallenged and people are less open to adaptation. While, according to Argyris, most people espouse a Model II approach (Smith 2001) their theory-in-use exhibits Model I characteristics. Model II learning involves use of quality data, seeking opinions of others regarding the situation or problem, and importantly the learner’s theories are made explicit and publicly tested.

In an organisational setting, individuals continually work to define the theory-in-use of the organisation and then define themselves within it (Argyris & Schön 1978). This approach acts to connect members of the organisation through interactions between individuals or within groups and is embedded in Argyris and Schön’s ‘organisational learning’ (Smith 2001). Single and double-loop learning can also exist at an organisational scale, in much the same way as at the individual level. Under single-loop learning the response to environmental changes is to use strategies to maintain the organisational theory-in-use. Double-loop learning involves scrutiny of the norms under which the organisation is run.

In critique of Argyris’ theory, authors have pointed out that much of the evidence supporting double-loop learning has been provided by ‘Argyris or his associates’ (Smith 2001). Nonaka (1994) also commented that double-loop learning is often seen as a special, difficult task – when it is actually a daily task for an organisation. Smith (2001) also criticises the Model I and II approach as ‘bi-polar’ and at risk of overlooking potential complexity and missing situations which exist ‘between the models’.

**Competency traps and incentives for change**

A key organisational learning idea of Levitt and March (1988) is that of *competency traps* which can occur when an organisation achieves favourable performance
from a process and accumulates experience with it to a point where their experience and level of comfort suppress uptake of a superior or more suitable process. This positive feedback loop can result in retention of less effective technologies or procedures long after they have been superseded. A similar idea was expressed by Arthur (1989) who identified technological ‘lock-in’ where a technology achieves enough market-share to become dominant and lock other technologies out. The difference between a competency trap and technology lock-in surrounds the role of learning. Competency traps arise when the new learning and system change associated with a new process outweighs the benefit of change. Technology lock-in involves the suppression of alternative technologies via proprietary means, rather than unfavourable learning demand.

Use of ICT provides a prime example of competency traps. Individuals in an organisation learn to enter data into a spreadsheet manually and develop templates specifically for the process. Although it is subsequently found that macro functions would be a faster data entry method not all the users are sure how to use macros and therefore prefer to retain manual routines. Of this Levitt and March (1988, p.322) commented:

‘Organisations learn to use some software skills rather than others, and refine their use of the systems they use. Efficiency of any particular procedure increases with use. Differences in success with procedures depends not only on performance potential of procedures, but also organisations competencies with them.’

The incentive to change from an ‘inferior’ process is driven by the difference in potential between the current process and any alternatives. The added benefit of an alternative needs to outweigh the negative impacts of organisational change and learning required to implement it.

**ICT and resolving equivocality through information**

Organising is defined by Weick (1969, p.11) as ‘the resolving of equivocality in an enacted environment by means of interlocked behaviours embedded in conditionally related process’. Information is collected and processed by organisations in order to reduce the equivocality within which they operate (Weick 1969). Equivocality exists where there are multiple interpretations to explain a
situation or problem. Organisation members discuss their competing interpretations in a search for a pre-eminent explanation.

In respect to this study, the use of ICT can be viewed with regard to the idea of equivocality and information. ICT is used to improve the processing of information, for example using databases to collate and organise data thereby reducing the equivocality associated with information rich environments. However, ICT can initially lead to increased equivocality as users adapt to the new technology (Wolfe & Cooper 2005). Highly flexible ICT systems, with extensive capability for refinement and modification, may also result in increased uncertainty for individuals within the organisation.

Equivocality of ICT systems relates to the difference between previous management practice and the practice under a new ICT system, termed ICT ‘radicalness’ by Wolfe and Cooper (2005). A high level of radicalness associated with the new system can impact on organisational learning processes. Reducing ICT-related equivocality requires users to be clear of the goals and functions for ICT within the organisation (Wolfe & Cooper 2005). This facilitates an awareness of the role of new ICT investments and provides a justification for individuals expending effort in learning new ICT systems. Also important is an awareness of the reorganisation and personnel training that will be required during the ICT adaptation process. The importance of these factors for reducing equivocality associated with dairy ICT use are examined through the experiences of case study farmers in this study.

**Communication cycles and loosely coupled systems**

Individuals react to changes in the organisational working environment by taking in information, interpreting it based on their personal experience and beliefs, and then taking action to address the change in a process Weick (1969) termed *enactment* (Figure 3.3). Action is the core idea of enactment and Weick identified action to be the first step in organising, identifying chaotic action as better than ordered inaction (Griffin 1991). People in the organisation then create and use *assembly rules*, or procedures, which help to give structure in approaching the information environment. The construction of assembly rules makes for a more
efficient learning process because they are used to set routines that minimise the processing of information.

Assembly rules are less applicable in environments of high equivocality and in this situation Weick states that people utilise *communication cycles* where they draw on the knowledge of others in the organisation, analysing the problem in order to make sense of the equivocality. Later in this thesis the importance of communication cycles in emerging precision dairying systems is discussed. Use of assembly rules or communication cycles form the *selection* process where a way forward is chosen for the organisation. If the selected approach proves successful then the assembly rules which guided it are *retained* for future use, if not then the process is repeated.

![Figure 3.3: A model of organising (Weick 1969, p.132)](image)

The enactment, selection, retention model can be applied to the introduction of ICT into a farming system. In this context the ecological change would be installation of a new ICT system, initially creating greater equivocality, as discussed above. Those on the farm interacting with ICT may first collect information about use of the new technology from the retailer and other farmers, but Weick’s model suggests that the ICT user should just act, or begin using the technology, if they are to reduce the equivocality. Through sitting down and using the computer software and individual cow information users can select the approaches that best fit their farming practice. Farmers then can chose to retain or reject aspects of the ICT, as observed in scoping study participants (Chapter 2) where some farmers rejected automated reports over time due to lack of apparent benefits. As Weick (in Griffin 1991) noted, excessive retention of assembly rules, such as retaining key automated reports, can result in inflexibility in response to future change.
Assembly rules should be continually challenged through reflection, for example asking ‘why am I using this automated report, is there another way of achieving the desired outcome’?

The key points in Weick’s abstract model are the retrospective sense-making that occurs in the assembly rule phase, the cyclical nature of sense-making in highly uncertain situations, and the danger inherent in creating inflexible rules that prohibit adaptation to future change in the organisations environment. Levitt and March (1988) described organisational learning as being routine-based, history-dependant, and target-orientated. They contend that organisations adapt their routines through either trial-and-error experimentation, or organisational searching. This process is similar to selection and retention phase proposed by Weick (1969), with organisational searching comparable to the concept of communication cycles.

March and Olsen (1975) and Weick (1976) disputed the historical approach of systems theorists which portrayed the links between elements of an organisation as constant, making organisations seem more stable than they in fact are. March and Olsen (1975) believe that these prior models mistakenly relied on closed loop cycles. In response to this Weick (1976) proposed that organisational subsystems were in fact loosely tied together ‘in the interest of self-determination, localised adaptation, sensing, and innovation’. The concept of loosely coupled systems was suggested by Weick (1976), where loose coupling is the ‘glue’ holding subsystems together. Loosely coupled systems can be identified by lack of coordination, absence of regulations, highly connected networking with slow feedback times, and the achievement of the same result via different paths (Weick 1976). The potential benefits of loose coupling in organisations include improved detection of changes in the environment, easier adaptation with potential for novel solutions to problems, subsystems are less affected by breakdowns elsewhere in the system, greater potential individual self determination, and lower administration costs (Weick 1976). However, potential negative features include difficulty in implementing systematic change, oversensitivity to changes such as short term ‘fads’, and difficulty in repairing subsystems or restoring network links.
A dairy farm enterprise can be viewed in terms of the loosely coupled systems concept. In general a dairy farm is a self contained learning system but it may be loosely coupled with other organisations, such as a discussion group or an industry organisation. It is through such linkages that communication cycles are used to analyse multiple interpretations of a particular issue. For example a farmer involved in a grazing management group may discuss the best way to determine pasture mass. Through communication cycles with other group members the farmer can begin to construct assembly rules that suit their own farming system.

Community of practice
The community of practice concept, developed by Lave and Wenger (1991), recognises the important role of informal social networks within organisational learning (Smith 2003). Community of practice focuses on learning as a social construction and a means by which individuals construct their identity (Brown & Duguid 1991). The communities refer to people united, often informally, by a shared purpose whether it is specifically working on a task or gathering as a discussion group. Members collaborate to share ideas, find solutions, and build innovations (Wenger 1998). Membership is participation-based rather than an official status and therefore communities of practice can span organisations. Wenger (2004, p.3) states that a community of practice is defined by three features:

- **Domain - What the community is about**
  
  “The area of knowledge that brings the community together, gives it its identity, and defines the key issues that members need to address. A community of practice is not just a personal network, it is about something. Its identity is defined not just by a task, as it would be for a team, but by an ‘area’ of knowledge that needs to be explored and developed.”

- **Community - How the community functions**
  
  “The group of people for whom the domain is relevant, the quality of the relationships among members, and the definition of the boundary between the inside and outside. A community of practice involves people who interact and who develop relationships that enable them to address problems and share knowledge”
• Practice - What capability the community has produced

“The body of knowledge, methods, tools, stories, cases, documents, which members share and develop together. A community of practice is not merely a community of interest. It brings together practitioners who are involved in doing something. Over time, they accumulate practical knowledge in their domain, which makes a difference to their ability to act individually and collectively”

Communities of practice exist in various forms and depending on their stage of development are either potential, coalescing, active, dispersed, or memorable (see Table 3.3) with their life cycle linked to the value provided to members. While communities of practice usually develop naturally they can be specifically developed or nurtured, however there is a risk that formalising them stifles their vibrancy and responsiveness.

**Table 3.3: Stages of development in a community of practice (Wenger 1998)**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Features of stage</th>
<th>Typical activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential</td>
<td>People face similar situations without the benefit of shared practice</td>
<td>Finding each other, discovering commonalities</td>
</tr>
<tr>
<td>Coalescing</td>
<td>Members come together and recognise their potential</td>
<td>Exploring connections, defining joint enterprise, negotiating community</td>
</tr>
<tr>
<td>Active</td>
<td>Members engage in developing practice</td>
<td>Engaging in joint activities, creating artefacts, adapting to changing circumstance, renewing interest, commitment, and relationships</td>
</tr>
<tr>
<td>Dispersed</td>
<td>Members no longer engage very intensely, but the community is still alive as a centre of knowledge</td>
<td>Staying in touch, communications, holding reunions, calling for advice</td>
</tr>
<tr>
<td>Memorable</td>
<td>The community is no longer central, but people still remember it as a significant part of their identity</td>
<td>Telling stories, preserving artefacts, collecting memorabilia</td>
</tr>
</tbody>
</table>

The CoP theory is not entirely separate from other theories of learning discussed earlier; in fact it incorporates notions of many of these other approaches. It is a more abstract theory than experiential learning and inherently involves reflective learning as members of the community discuss problems, ideas, and potential
solutions. The emphasis on linkages is similar to Weick’s concept of loosely coupled systems. Loosely coupled systems involve linkages between self-determined organisations, whereas communities of practice focuses on people working together to generate collective knowledge. Lave and Wenger (1991) use the term ‘legitimate peripheral participation’ to describe this engagement in social practice where learning is an integral constituent. CoP are seen by Brown and Duguid (1991) to equate to the enacting organisation described by Weick (1969) in that they are capable of reconceiving their own identity and are reflectively structured.

Wenger (1998) views change to be a learning process and suggests that effective change involves ‘negotiation of meaning’, and that this negotiation is comprised of reification and participation within communities of practice. Reification involves taking abstract ideas and formalising them, as a tacit to explicit knowledge transfer akin to Nonaka’s ‘externalisation’. Participation implies that CoP members are actively involved in the process, not just translating knowledge but engaged in a continuous recontextualising of its meaning thereby maintaining knowledge in a ‘living’ form.

Community of practice theory fits well with the development of precision dairy systems. The emergence of precision dairy systems involves primarily informal linkages between individuals and organisations around the shared goal of implementing precision dairying techniques and practice. The development of these linkages evolve over time in much the same way as Wenger (1998) describes in terms of ‘potential’, ‘coalescing’ and ‘active’ communities. Also central to the emerging precision dairy system is the reification of abstract ideas, and translation of knowledge. These concepts are discussed in greater detail in Chapter 5.
3.2.3 Farmer-specific learning and the role of advisors

Theoretical models of farmer learning

Farmer learning and learning styles have been addressed by several authors including Roling and Jiggins (1998), Kilpatrick and Johns (1999), Kenny and Paine (2001), Thomson (2002), and Fulton et al. (2003). While specifically addressing farmer learning, these authors have uncovered learning characteristics that fit with the general individual and organisational learning theories discussed above. For example, Petit (1997, in Gray 2001) believed farmers operate via mental models, which are revised as they adapt to change and that learning occurs via validation of a tested model. Finding a model invalid causes a rejection of the hypothesis and use of a corrected model, a fundamental learning process. This mental model approach is similar to the enacting, selection, and retention learning process of Weick (1969) discussed previously.

Kenny and Paine (2001) also described farmer learning in terms of a mental model. They identified a performance triangle model driving dairy farmer grazing management practice. The model consisted of three elements:

- The perception of options where the farmer uses those options perceived as relevant to their situation. Often they may chose an option based on historical practice;
- A feasibility appraisal which is continually occurring. It involves the farmer posing the question ‘is it feasible to continue with this activity?’
- A task specific reality check where the farmer checks to see if the option used is actually performing as expected.

Farmers did not use these processes in isolation as they are also influenced by intentions which consist of goals, objectives, and desires. Intentions themselves exist in tension with a perception of internal and external barriers. Internal barriers are those within the farmers control and relate to the way an individual manages their farm. External barriers are those outside of the farmer’s control, such as milk prices. A farmer’s worldview is a final but critical determinant of their ability to learn and reflect.
Kilpatrick and Johns (1999) found that Australian farmers preferred learning from informal sources rather than training due to a preference for independence, familiarity with a highly contextual learning mode, lack of confidence in working in training settings, preference for information from known sources, and a fear of being exposed to new knowledge and skills. Farmers preferred to learn in an informal setting from ‘networks of known contacts’ and the most effective training was ‘interactive, relevant, delivered to groups who feel a sense of commonality and presented by credible facilitators in short sessions at convenient times and locations’ (Kilpatrick & Johns 1999). Fulton et al. (2003) stated that farmers learn through a combination of approaches including reading, experts, other farmers, the media, observation and experience, groups, field days, seminars, conferences, and organised training or education. While national statistics indicate a low level of participation by Australian farmers in education and training, it may be a misleading indication of actual farmer learning because farmers learn in a continual and informal process based on workplace experience (Fulton et al. 2003).

In a parallel to communities of practice theory, Kilpatrick and Johns (1999) highlighted farmer learning as a socially imbedded, continuous process. Farmer support networks are important for successful implementation of change, and an important factor is interaction with peers. Through this process farmers can compare opinions on use of information, test each others values and beliefs, and subsequently adjust their own views and attitudes (Kilpatrick & Johns 1999) in a process comparable to the reflective practitioner of Argyris and Schön (1978). The authors suggest that for learning sources to match the specific needs of farmers, other farmers should be used for decision making and practical issues while extension officers and consultants are used for technical advice. This has implications for ICT training approaches as discussed in subsequent chapters. While Kilpatrick and Johns (1999) highlighted farmer learning preferences, they did not explore relationships behind the networks of known contacts, or in which particular situations the knowledge of peers was useful.
The farmer to service provider relationship

Farmers are entrepreneurs who complement their knowledge base with support of advisory or consultancy services (Paine et al. 2004b). These service providers therefore become a component of a farmers learning process with knowledge exchanged between the two parties. Kilpatrick and Johns (1999) categorised farm management into learning patterns based on the use of off-farm information sources. The four learning patterns represented learning of the whole management team as a collective, rather than a farmer as an individual, and are as follows.

- Local focussed: source advice from local experts and local farmers
- People focussed: consult two or more people and no more than one other learning source. Learn from people in one-on-one or in farmer directed groups
- Outward looking: use a variety of sources, and consult three or more sources when making a change
- Extensive networking: use a wide range of sources (at least four of training, experts, other farmers, agriculture organisations, media, overseas or interstate observation, trials or experiments for research purposes).

The patterns are useful guides of learning behaviour but may present an overly simplistic view of the learning complexity within a farm management team as they are primarily based on the number of learning support sources used. The learning pattern may also differ depending on the nature of the change, for example when faced with a significant learning challenge the management team may use extensive networking but for a minor learning challenge they may be more locally focussed.

Paine et al. (2004b) contrasted the farmer learning situation of Kilpatrick and John (1999) with the role of advisors and cited the need for advisors to be more than “walking reference manuals” and to be amenable to adaptation according the particular farmer needs. To better understand learning needs, advisors should form a “learning partnership” with farmers by distinguishing between learners’ actions, intentions and worldviews, and then making sense of interactions between these factors (Paine et al. 2004b).
Service providers can act to expand a farmer’s worldview by creating a tension between a farmer’s embodied worldview and a challenging worldview that questions the assumptions underlying their actions (Kenny and Paine 2001). A study of 75 professional advisors in the Australian dairy industry found that while advisors might perceive a need to challenge a farmer’s worldview, the farmer might feel they are actually performing adequately (Paine et al. 2004b). This creates a potential disconnect for service providers looking to support farmer learning where farmers themselves do not perceive such a need exists. Such a disconnection has important implications for learning support structures around dairy ICT systems investigated during the case study. For example if ICT service providers fail to place enough emphasis on challenging the worldview of ICT users by identifying advanced ICT applications, farmers may not move beyond a basic application and integration of ICT into their management practice.

3.2.4 Summary of theoretical perspectives

The theoretical perspectives discussed in this chapter provide a lens through which to analyse farmer learning of new dairy ICT and the development of precision dairy systems. Learning processes of farmers fit within the wider individual and organisational learning models, developed by social theorists over the last three decades in particular. Four key themes from the theoretical perspectives proved relevant to the experiences of the case study farmers and their role in emerging precision dairy systems:

Implications for knowledge creation in precision dairy systems
Emerging precision dairy systems can involve a shift in knowledge creation processes for farmers. Where previously knowledge was derived primarily through experience and stored in a tacit form, an ICT-based practice requires knowledge to be explicit in the form of stored data and set parameters. Nonaka’s (1994) theory of organisational knowledge creation highlighted the importance of the tacit to explicit knowledge conversion process to enable people of differing skill backgrounds to exchange information and learn from each other. In later chapters this process is discussed in terms of learning networks between farmers, retailers, and other people involved in emerging precision dairy systems.
Managing the change between old and new knowledge management systems

Potential issues during adaptation of dairy farm knowledge management systems were raised by Levitt and March (1988), Arthur (1989), Weick (1969), and Wolfe and Cooper (2005). According to these authors the utilisation of new knowledge management systems can be impacted by competency traps and increased equivocality. These are key issues for farmers learning to use new dairy ICT and adapt their management practice to incorporate regular individual cow data.

Incorporation of reflective practice in emerging precision dairy systems

The importance of reflection in the learning process of individuals and organisations was highlighted through the work of Nonaka (1994) and Argyris and Schön (1978). Learners who reflect upon the governing variables guiding their actions are able to respond to changes in their environment. Reflection and testing of theories-in-use requires interaction with others, emphasising the need for learning networks. Such networks are of particular importance for farmers learning to use new ICT systems, and therefore the concept of reflective learning is used to assess learning support systems present in the emerging precision dairy systems studied.

Potential importance of learning networks in emerging precision dairy systems

The organisational learning theory emphasised the importance of interaction between people in the learning process. Emerging precision dairy systems can involve a major shift toward use of objective data. The interaction between farmers and off-farm actors who are skilled in the application of such data is vital for the successful integration of intensive data into farm management practices. The concepts of loosely coupled systems (Weick 1976) and communities of practice (Lave & Wenger 1991) provide a framework for discussing the human interaction in emerging precision dairy systems.

The next section outlines the method used to investigate the learning and adaptation issues in emerging precision dairy systems. A grounded theory
approach was used and the method was guided by the issues arising from the scoping study rather than being specifically driven by the theoretical perspectives outlined above.
3.3 Research design

3.3.1 Introduction
The scoping study in chapter two highlighted the importance of the implementation phase in the development of precision dairy systems. Many participants in that study spoke of the first 6-12 months as being the most difficult learning period, a period where they were faced with learning to use new software, interpret data, and adapt their approach to match changes throughout the season and lactation. From these findings a further study was proposed, to focus on this key learning stage. While the scoping study provided direction for additional study, it also highlighted that an exploratory approach was required to collect a rich picture of developing precision dairy systems at the farm business level. This section provides an outline of the guiding research questions and methods used in a study of the key learning phase of farmers using dairy ICT and adapting to precision dairy practice.

3.3.2 Research questions
The research questions guiding the case studies of farmers using PDF-ICT were:
1. How do farmers adapt their management practices to incorporate PDF-ICT systems?
2. What learning support networks exist around PDF-ICT systems?
3. What interventions are required for future precision dairy systems?

3.3.3 Selection of research approach
In his review of social research methods, Bryman (2001) identified five different research designs: experimental, cross-sectional, longitudinal, case study, and comparative. The stated research questions for this study fit best with a mixed longitudinal-case study approach where the case is Australian dairy farmers using precision technologies. Gummesson (2000, p.120) describes case studies as the means “to get access to the complex realities that belong to the hidden part of the iceberg, the 90% under the surface”. This fits with scoping study findings which highlighted a need for in-depth examination of emerging precision dairy systems. A
longitudinal study enables observation of changes in learning over time, a recommendation from the scoping study. Longitudinal studies allow emerging issues to be uncovered over time, with the researcher building knowledge of complex and relatively unknown areas of enquiry. The longitudinal design used in this study represented (see 3.3.5) a ‘cohort study’ (Bryman 2001) where the same participants were interviewed each time. The ability to reinterview participants over time enables a rich picture to be built of the PDF-ICT learning and adaptation process, along with documentation of changes to this process through time. It should be noted that while a longitudinal approach was adopted for this study, it only refers to an 18 month time span which is relatively short in terms of classic longitudinal studies.

Results from the scoping study highlighted a steep learning curve for PDF-ICT users and that when users reflected back on this period they tended to forget and consequently under-rate the learning challenge compared to those new users still in the early learning phase. A longitudinal case study method, starting at pre-installation, was therefore chosen to follow new users through the first 18 months of operation to encompass the key learning period.

The case study was undertaken using an inductive perspective that included data collection via both participant observation and grounded theory. Grounded theory was appropriate in this study due to the lack of prior research conducted in the topic area, and because it facilitates main issues to be revealed without pre-determined bias. An inductive approach was employed to allow an exploratory study of precision dairy systems, a genre that has received little attention from researchers as discussed in Chapter 2. Grounded theory is differentiated from other forms of qualitative research by an emphasis on theory development (Strauss & Corbin 1998). Data collection drives the development of theory via constant interaction between data, analysis, and theory development (Strauss & Corbin 1998). Conducting pure inductive research is difficult as researchers invariably possess a degree of pre-understanding of the topic and potential outcomes (Gummesson 2000). In this study some researcher pre-understanding is acknowledged due to prior investigation of the topic and from the scoping study outcomes. However, this research was designed to uncover issues behind farm
management practice adaptation on the case study farms through use of semi-structured interviews and ongoing analysis throughout the case studies. The risk of bias from pre-understanding was also addressed through use of data triangulation discussed in the next section on research quality considerations.

Case studies generally fall into one of three categories: explanatory, descriptive, or exploratory (Yin 2003). Descriptive case studies involve observation of new products or processes and analysis of their adoption (Gummesson 2000). Explanatory research is often used to study processes and offer explanation for them. This study fits into the category of an exploratory case study which consists of pilot research aimed at providing information to guide subsequent development of more precise questions (Gummesson 2000).

3.3.4 Designing case studies

Research quality considerations

Research quality within social research disciplines is generally associated with reliability, replication, and validity (Bryman 2001; Yin 2003). Reliability is related to the stability of research findings over time and the ability to achieve similar outcomes using different researchers or methods. A method is said to be reliable if it can achieve similar results when used again in similar circumstances. There are two types of reliability, internal and external. Internal reliability relates to whether the method used is consistent within the study itself. Whereas external reliability (validity) relates to whether the study could be repeated with similar results, and a key factor in this is transparency of method.

Validity in social research is of key importance as it is concerned with the integrity of the findings. Four factors combine to constitute validity: measurement validity, internal validity, external validity, and ecological validity (Bryman 2001). Measurement validity considers whether the research method used is actually measuring the right concepts. Internal validity deals with causality in the research, in other words is the link between observations and the subsequent conclusions valid or are other factors involved? External validity is concerned with the ability to generalise findings beyond the research boundaries. The final aspect, ecological
validity, involves assessment of whether the research findings actually represent how people live their lives when viewed in a social setting.

In this study the one key researcher (the author) was guided by reflection from PhD supervisors and department colleagues. In terms of internal reliability this ensured the same ‘lens’ was used across case study farms, and although a semi-structured approach was used the basic framework of questions and themes was applied across all farms. External validity can prove a challenge in studies with a small number of cases where it is difficult to generalise findings across a wider population. In this case study, findings were compared to relevant learning and knowledge theory to enable a ‘step back’ and view of the outcomes in a broader theoretical sense. General farm information was also collected to enable participant farms to be positioned within the wider Australian dairy industry.

While the researcher was not directly involved in installation, maintenance, or training of the ICT on the farms studied, some researcher influence was still possible due to the fact the participants were being asked questions and made aware about learning and features of ICT use. Also, examples of potential information use or training approaches were used as prompts during interviews, and this may have influenced the participants’ perceptions of their own use or provided them with ideas for future use. To address internal validity implications a post-interview analysis check-sheet was filled out by the researcher to identify any possible researcher influence on participant ICT use.

Measurement validity was addressed in the case study through use of triangulation via multiple data collection methods (interviews, observation) and multiple sources (farmers, ICT technicians). Use of feedback and review from both participant farmers and relevant ICT technicians aided reliability and validity.

**Managing risk in research**

In any research method there are risks to successful study completion which need to be identified and managed. The following risks were identified for this project in the proposal phase and risk minimisation strategies devised:

- Lack of participants
In the study design phase there was little information available on the number of farmers installing the applicable technology making it difficult to estimate the ease with which the required number of participants would be achieved. To account for this the study design was not overly prescriptive in terms of farm size, farm structure, or specific technology manufacturer.

- **Participant withdrawal**
  Use of a case study design based around a small number of farms makes the impact of participant withdrawal significant. The multiple-visit and in-depth nature of the method also raises the risk of withdrawal due to changed participant circumstances or participant fatigue. The risk of a participant withdrawing from the study was managed by ensuring every participant was aware of the time and information input expected prior to study initiation. Keeping participants up to date with research progress and providing them with feedback was used to maintain their interest and enthusiasm for the work. Developing a rapport with participants is also important and this was achieved through explaining the project, respecting comments, maintaining confidentiality, and continuing contact between interviews (Seidman 1998, in Gray 2001).

- **Adaptation of research focus**
  The use of a grounded theory approach inherently involves the potential for uncovering of unexpected issues that require adaptation of the research focus and/or method. Accordingly, interim results from participant interviews were reviewed after each interview and data analysis was conducted parallel to data collection. Prior to each interview a farm-specific semi-structured interview guide was compiled to ensure emerging issues were revisited.

**Social researcher role**
The researcher role was primarily that of observer, however inadvertent influence on participant behaviour was possible through the semi-structured interviews making the role slightly participant observer. The potential impact of the researcher on each case study farmer was monitored throughout data collection through completion of a critical reflection sheet after each interview (Appendix 4), and by specifically including researcher influence in the data analysis method. At the completion of the study, participant farmers were also given the opportunity to
review a written summary of their experiences. Potential ethical issues were also addressed via submission of a project outline to the departmental human ethics committee, and consent was obtained from participants using a plain language statement (Appendix 5) and consent form (Appendix 6).

**Unit of analysis**

In qualitative research the unit of analysis is the major entity being studied. In this study the unit of analysis is farmer use of milk meter based EID technology.

### 3.3.5 Case study method

**Selection criteria**

Case selection was driven by the research questions and by logistical considerations. Gray (2001) highlighted two factors to consider when selecting cases: the criteria used to select the case, and the number of cases that should be studied. The key criterion for case study farms was the installation of electronic identification, inline milk meters, and individual feeding (Table 3.4). A study start date of mid-2005 required suitable farms to be installing the appropriate technology during that period. Victorian dairy farms were initially sought in order to minimise researcher travel time however a low number of applicable installations forced the geographical boundaries to be widened to include New South Wales farmers. In total six farms were sought in a trade-off between observing ICT use in a wide range of dairy systems and the constraints of time and availability of suitable farms. This number of cases also matched guidelines stated by Yin (2003).

<table>
<thead>
<tr>
<th>Factor</th>
<th>Selection criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ownership structure</td>
<td>Family/partnership</td>
</tr>
<tr>
<td>System installation</td>
<td>June-August 2005</td>
</tr>
<tr>
<td>System manufacturer</td>
<td>At least two different manufacturers</td>
</tr>
<tr>
<td>System components</td>
<td>Electronic identification, milk meters, individual feeding</td>
</tr>
<tr>
<td>Commitment</td>
<td>A willingness to be fully involved in the project</td>
</tr>
<tr>
<td>Location</td>
<td>Victoria and New South Wales, Australia</td>
</tr>
</tbody>
</table>

Bryman (2001) identified three possible sampling methods: convenience sampling, probability sampling, and theoretical sampling. A convenience sampling approach was adopted for this study due to the low number of potential participants.
applicable under the selection criteria. There was no opportunity to adopt a random selection method or use a targeted theoretical selection process as illustrated by the need to expand the geographical criteria to include New South Wales in order to ensure sufficient participants.

Potential participants were identified primarily through personal contacts and secondly via technology retailers. Utilising personal contacts was preferred to minimise the potential for retailers to select participants or for the research to be seen to be affiliated with any particular company. However due to difficulty in finding appropriate installations the researcher ultimately approached milking equipment retailers directly to achieve the desired number of cases.

**Recruitment and data collection**

Selected participants were initially approached over the phone and then posted a project outline, including a plain language statement, if interested in being involved. Only one potential participant declined to be involved. The project outline listed project objectives, importance of the research to the participants and the wider dairy industry, the researcher’s role, time involved and expectations. A follow-up phone call confirmed each farmer’s continued participation whereupon an initial interview time was arranged.

Personal and farm characteristics of each case study participant are outlined in Table 3.5. Each farmer is referred to by a pseudonym, and on two farms a husband and wife team were collectively viewed as one ‘case’. Other people referred to in the following chapters or directly involved in the study are listed in Table 3.6. They are either ICT retailer employees or contracted experts.

<table>
<thead>
<tr>
<th>Table 3.5: Characteristics of participants and their PDF-ICT systems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Participant age</strong></td>
</tr>
<tr>
<td><strong>Region</strong></td>
</tr>
<tr>
<td><strong>Initial herd size</strong></td>
</tr>
<tr>
<td><strong>Calving pattern</strong></td>
</tr>
<tr>
<td><strong>ICT history</strong></td>
</tr>
</tbody>
</table>
### Table 3.6: Details of other people involved in the case studies

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>ICT system association</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trainer-1a</td>
<td>ICT-1</td>
<td>Support technician</td>
</tr>
<tr>
<td>Trainer-1b</td>
<td>ICT-1</td>
<td>Former dairy farmer and ICT-1 user, independently contracted trainer</td>
</tr>
<tr>
<td>Trainer-1c</td>
<td>ICT-1</td>
<td>Sales and support manager</td>
</tr>
<tr>
<td>Trainer-2a</td>
<td>ICT-2</td>
<td>Dairy farmer and ICT-2 user contracted by retailer to deliver on-farm training</td>
</tr>
<tr>
<td>Trainer-3a</td>
<td>ICT-3</td>
<td>Support technician</td>
</tr>
</tbody>
</table>

Semi-structured interviews were used to explore the themes of learning, training, decision-making changes, and information utilisation. The semi-structured interview method is appropriate where little information exists about the nature of the phenomena studied (Gray 2001). Interviews were based around an interview guide, a written list of questions and topics to be covered, and the order in which to cover them, but the researcher was able to follow leads during the interview.
(Bernard 1988). The initial interviews with each case study farmer were based on a standard interview guide. Subsequent interviews built on individual characteristics of each case study, guided by the themes of learning, training, decision-making, information utilisation, and adaptation. Specific examples of questions used in the interviews are provided in Appendix 1.

Participant observation was used as a secondary data source along with analysis of each participant’s specific ICT database. Observation included watching the participants during milking and asking them to show the aspects of the computer software they used. Informal conversations were held with the trainers (Table 3.6) as a form of triangulation of the case study farmer interviews. The data from these conversations are not directly used in the following chapters, but were useful in guiding subsequent case study farmer interviews and in providing a broader perspective on the issues.

**Data analysis**

All interviews with case study farmers were recorded and transcribed, then thematically analysed using NVivo™ qualitative research software. Data analysis was conducted throughout the case study as data were collected, and preliminary results were delivered back to each farmer at the conclusion of the final visit for their comment. Their comments were used for triangulation and quality control in data analysis. At the final draft stage of the thesis each participant farmer was provided a copy of the analysis of their own experience (see Chapter 4). Farmers were invited to comment on the analysis and these comments were used to add rigour to the discussion.

The first step in analysis of each interview involved a short post-interview analysis, completed directly after the interview. It entailed listing ten main themes arising in the interview, along with answering several self-reflection questions aimed at uncovering questions that may have been missed or methods to improve future interviews. In the initial stages of the study the main themes from each interview were reflected in early coding themes.
Transcribed interviews were analysed initially using the open coding method described by Strauss and Corbin (1998). Open coding enables the researcher to ‘break open’ the data into abstract conceptual categories. This process of open coding drew on the post-interview analysis themes and was expanded by coding sections of the transcripts to create new categories. Axial coding was used to ‘reassemble’ the data split up in the open coding process by making connections between categories (Strauss and Corbin, 1998). While open coding is the initial approach adopted, often open and axial coding occurs interchangeably, as was the case in this project when new themes arose over the study period. This approach fits with the constant comparative process of grounded theory. Major themes uncovered during qualitative analysis were denoted by memos, for example ‘reflective learning processes’. These memos were used to record key thoughts of the researcher during the coding process. Use of NVivo7 allowed the original source in the transcript to be linked to the relevant memo.

The coding and memo process uncovered main themes around learning and adaptation which were then contextualised in respect to the existing theory reviewed earlier in this chapter. Aspects of these theories were used to explain the experiences of the case study participants, and to facilitate generalisation beyond the bounds of the six farms studied.

3.4 Guide to the case study chapters

The discussion of learning theory and case study methodology in this chapter was aimed at positioning the reader for the two chapters (4 and 5) which follow. This does not reflect the actual order in which the research was organised. In line with a grounded theory approach, the case study research was conducted before the application of established social theory. In this thesis the theory has been presented first for the benefit of the reader. In Chapter 4 participant experiences on the six case study farms are described as they learn to use ICT and adapt to precision dairying practices. The key emergent learning from each case farm is reviewed and summarised at the end of Chapter 4. These emergent themes then form the basis of a cross-case analysis in Chapter 5 where the implications for emerging precision farming systems are discussed.
4.

Farmer learning in precision dairy systems: Using PDF-ICT as a case

4.1 Introduction

In this chapter the findings of a six-farm longitudinal case study are presented where the implementation of herd management software and associated sensor technology over an 18 month period is described. A standard framework is used to describe and analyse each case study farm. Each farmer’s learning experiences with the new PDF-ICT are first outlined through a review of the farmer’s background and identification of the significant events. The critical issues are then identified in relation to learning, adaptation, and the development of a precision dairy farming system. At the end of each section the emergent learning is analysed to form the basis of a subsequent cross case analysis (Chapter 5). A summary concludes the chapter and identifies the primary issues relating to the emergence of a precision dairy farming system.

The stories of all six farmers are described under a pseudonym to protect their privacy, with each case assigned a theme to reflect their experience with PDF-ICT (adapted from Nettle et al. 2006). While the names have been changed, their actual gender remains accurate and therefore the predominance of male pseudonyms reflects reality rather than a gender bias. Specific PDF-ICT brand names have been replaced with ICT-1, ICT-2, and ICT-3 (Table 3.5) to retain a focus on the influence of technology characteristics, rather than the specific product. Other participants in PDF-ICT learning on each farm are the PDF-ICT
technicians employed by each retailer to support the learning process who are also given pseudonyms, for example Trainer-1a and Trainer-1b supported ICT-1.

4.2 Mr A – The process of unlocking potential

4.2.1 Case description

Mr A ran a 4th generation Gippsland, Victoria, dairy farm in a 50:50 income-expenses partnership with his parents. Married to a fulltime midwife he had worked on the farm for 15 years. Now in his early thirties he left school at year 11 and completed a four year dairy apprenticeship, 40 percent of which was based on another farm. The management of the farm was in a transition with Mr A’s father stepping back from day-to-day management. Although his father was still involved in strategic decision-making, Mr A was the primary decision-maker in respect to tactical and operational management. He used several off-farm resources for advice and information, including a nutrition consultant, young farmers group, and a respected neighbour. Even with a self-confessed ‘cruisy’ management style, Mr A believed in ‘doing it once and doing it right’.

At the start of the case study in 2005, 240 cows were milked at peak on 100 ha non-irrigated pasture, with up to 1.6 t grain/cow/year fed in the dairy – above the national average of 1.45 t grain/cow/year (Dairy Australia 2007). In addition to the main farm, a separate 34 ha was used for young stock and 20 ha for dry cows. The Jersey herd was managed in a split calving pattern (1/3 autumn, 2/3 spring) with approximately 85 replacements per year reared on-farm, 50 of which were kept and the excess sold. Milk was sold through a milk broker with 60% used as the sole input for a high quality cheese line at a local factory. Production was 6000 litres/cow in 2004. Short term goals included producing 7000 litres/cow/year, repaying debt on the new dairy in five years, and building the business to enable a manager to be appointed. Drought and high costs of purchased feed during the case study period impacted on production with 310 cows producing 5400 litres/cow in the 2006/07 season.
Herd management software, initially PCFarm™ and latterly EasyDairy™, had been used on the farm since 1991 to record herd test information and data on matings, health treatments, drying off, and calvings. The data were manually entered by Mr A’s father approximately weekly and consulted daily. A paper diary of herd events was also maintained. Herd testing was conducted on a monthly basis and general herd condition scoring was undertaken by the nutrition consultant periodically.

4.2.2 Significant events

A 30 year old 10-aside double up herringbone was replaced in 2005 with a new 20-aside rapid exit shed that included collar-based EID, milk meters with conductivity, auto-drafting, automatic cup removers (ACRs), auto teat spray, auto washing, and a single-head automated feeding system. The system was administered by ICT-1 software on a computer easily accessible in an office near the pit. Mr A invested in the IT technology to enable individual feeding and improve labour efficiency but beneath these goals was also a desire to improve the timeliness of decision-making and exert greater control over the farming system in the areas of mastitis detection, heat detection, and herd health. Mr A felt that monthly herd testing was not timely enough for use in individual feedings decisions.

While expecting accurate cow identification, pre-purchase discussions with users of similar systems who had experienced misreads left Mr A prepared for a small margin of error. He initially viewed the system as another management aid, rather than something to fully rely on. As a result Mr A had an awareness of potential problems with ID and adapted his milking procedure to include checking the number of the last cow in the bail. The retailer instilled an expectation of software compatibility between EasyDairy and the new system. This proved not to be the case, with only limited historical cow pedigree data able to be transferred. This was a contributing factor in Mr A’s decision to continue using EasyDairy alongside ICT-1.

The new ICT system (ICT-1) installed on Mr A’s farm was implemented with few technical problems and this allowed Mr A to gain confidence with the system and
begin to incorporate it in his management soon after installation. Prior use of herd management software provided Mr A with a kick-start in his learning of ICT-1. Mr A had never received any formal IT training prior to purchasing ICT-1, but his confident attitude towards the use of computers and willingness to spend time learning were key features of his learning style.

The technology supplier provided a prescribed training regime as part of the package price, including one-on-one training sessions, off-farm group training, and remote (phone and email) support. Initial training was provided pre-installation (June 2005) in the form of a group training day off-farm which Mr A found useful in terms of its hands-on nature and provision of background knowledge.

Milking and use of ICT-1 began in the new dairy in July 2005 and shortly afterward Mr A received a one-on-one on-farm training session. This session, with a technician from the company head office (Trainer-1a), provided basic start-up training on how to enter data and extract key reports. Mr A found the session useful but commented after three hours of one-on-one training his ability to absorb more information had fallen. At this point of his learning process it was easy to feel overwhelmed by the data and options:

‘To be honest at this stage it is still pretty new and stuff, I still can’t do a lot on it, you know like entering stuff on it, you get part way through and you get a bit lost.’ (Mr A, August 2005)

Between July 2005 and June 2007 no additional formal training was delivered although company technicians visiting the farm to fix technical problems were able to provide Mr A with tips on any questions he had. A large manual was supplied with the software but Mr A found it too complex. He commented that he was thinking of making his own more basic manual as a guide for himself and his staff, but this was not undertaken by the end of the case study. Phone and email support proved a crucial learning tool because it allowed Mr A to deal with specific queries as they arose. A typical example was the creation of new reports in the ICT-1 software where Mr A would attempt to construct his own report but would contact the Trainer-1a for advice if required. On several occasions the technician built the
report and emailed the file to Mr A within 24 hours. In an effort to encourage self-learning Mr A reviewed the reports to determine their construction, with the view to being able to write such reports himself.

A key learning point occurred approximately two years after installation. In June 2007 the ICT-1 supplier held an off-farm group training day, run by a former dairy farmer (Trainer-1b) who was skilled in the use of ICT-1. A simplified user manual, written by Trainer-1b, was also given to attendees. Mr A attended and found the training highly useful, stating that he learnt more in the subsequent month than he did in the last 2 years about how to utilise the software and information. He also preferred the simplified and more visual worksheets developed by Trainer-1b compared to the large formal ICT-1 user manual. Another factor behind increased utilisation was the employment of a new staff member in November 2006 who was enthusiastic about using ICT and individual cow data to improve farm efficiency.

Specific examples of Mr A’s learning are illustrated below via the use of ICT-1 in two key decision-making areas, mastitis detection and feed allocation.

Conductivity in mastitis identification
Use of conductivity information for mastitis identification represented a gradual journey for Mr A. Previous practice was to use somatic cell content (SCC) data from monthly herd testing, along with visual detection. Tacit knowledge based processes such as visual checking for mastitis were formerly a large component of Mr A’s day-to-day decision making and it took time for the new data sources to be incorporated. Soon after installation, Mr A was faced with a SCC spike leading to loss of premium milk status. His reaction was to use a process driven by identification of high SCC cows from herd test results, then setting an automated ‘milking stop’ alarm to catch cows for manual stripping prior to cups-on. Aside from using ICT-1 for the auto-stop alarm this approach represented little change from pre-ICT-1 practices and utilised data up to one month old. Conductivity readings began to play a decision-making role within three months of installation. A high cell count report from the factory triggered Mr A to visually review conductivity graphs to identify abnormal cows. Cows highlighted via this process were then individually assessed via the same method as Figure 4.1(i).
Using daily conductivity data in place of herd test figures that could be up to one month old (Figure 4.1(ii)) led to improved timeliness but was reactionary and did not represent a great step forward in efficiency. A more proactive and efficient approach was adopted by Mr A late in the case study, and was directly related to the additional training received in June 2007. During this training he was shown how to use ICT-1 to automatically alert him when a cow exhibits combined abnormally high conductivity and low milk yield for two or more consecutive days (Figure 4.1(iii)). High frequency data became the new trigger for an action to be taken.

![Figure 4.1: Mr A’s mastitis detection process](image)

**Using milk yield data for individual feeding**

Mr A also took an incremental approach to using the individual cow supplement feeding capability of ICT-1. In learning to use this technology he primarily forged his own path, occasionally consulting his nutritionist and ICT-1 technicians.
'I’m going to talk to one of the guys up there (nutritionist) particularly about the individual feeding and feeding to production, pushing them (the cows) to respond to the litterage, they have some people up there who know what’s going on with that’ (Mr A, August 2005)

There were two aspects to his learning: using the software, and using individual daily milk yield data. Initially his goal was to implement individual feeding within two weeks of installation, but after two months an incorrect software setting was found that had led to all cows being fed only the base 3.5kg ration. The fault was discovered by Mr A when he realised that overall grain use was too low and identifying the cause of the fault, a setting originally made by ICT-1 technicians and later investigated by the technicians, took “a bit of time” according to Mr A. While this exhibited a lack of knowledge by technicians, it did not have a noticeable impact on Mr A’s confidence in the technical support offered.

From March to July 2006, cows were split into two physically separate groups, ‘fresh’ and ‘stale’ cows, primarily to aid identification of animals in oestrus. Full individual feeding, based around two virtual herds with separate individual cow feeding regimes, was instigated in August 2006, one year after installation. Mr A initially consulted his nutritionist to design the individual feeding regime but subsequently undertook his own modifications during lactation by “constantly tweaking” feeding categories. Minor changes were triggered by factors such as available pasture and abnormal weather. Mr A developed a routine of reviewing 7 and 30 day average milk production by group (stale and fresh) and relating them to tacit decision rules. He used his consultant’s six-weekly cow condition scoring to review the success of his own feeding regime.

4.2.3 Critical issues
Milk meter-based ICT represented a significant additional investment for Mr A, yet his steady learning curve didn’t allow him to unlock some of the major benefits until 12-20 months after installation. This gradual unlocking of capabilities was a result of Mr A’s learning approach and the effectiveness of external training as discussed below.
Mr A exhibited a strong ‘learning-through-doing’ approach to the new technology, and was classified as a ‘Converger’ in a Kolb learning style test (Kolb 1984). The ability to learn through experience was partially hampered by an attitude that time on the computer was less beneficial than time elsewhere on the farm. Although competent and confident at the computer, his large leap in learning came only after specific usefulness was demonstrated to him in the June 2007 training. This indicates a need for dairy ICT users to situate potential uses of the technology in their own farm management context, in order for them to ascertain specific outcomes and weigh them against required time and learning inputs.

While self-learning was a key aspect of Mr A’s ICT-1 development, he was supported by ‘outsiders’ in various forms. He attended two workshops, one prior to installation and the other 20 months after installation, had two formal one-on-one on-farm training sessions, and ongoing email and phone contact with technicians. Mr A expressed a preference for training run by people he perceived to have adequate knowledge of dairy farming systems and he viewed the ICT-1 supplier’s primary software support technician (Trainer-1a) as having limited practical dairying knowledge.

‘I know that one of the tech guys is previously a Vet, which is probably fairly handy from a farmers point of view, like they’ll be on a different wavelength from a computer person’ (Mr A, August 2005)

A major increase in ICT-1 understanding, according to Mr A, resulted from interaction with Trainer-1b who was also a former dairy farmer. Two factors were behind this increase: firstly Mr A found the training to be easy to understand and highly applicable to his operation, and secondly he had already developed a base knowledge of ICT-1 enabling him to interpret the value of the trainer’s suggestions. While such a base knowledge is required to unlock more complicated ICT functions, Mr A could have benefited from more advanced and practical training up to a year earlier.
As part of his experiential learning style, Mr A exhibited reflective practice in his use of *ICT-1*. Responding to management issues, he adjusted key parameters such as milk flow threshold for ACR detachment, milk yield deviation alert level, and auto teat spray settings. Mr A primarily used his own experience and intuition, but also sought advice from *ICT-1* technicians and his nutritionist. This process aligns with Nonaka (1994) who emphasised the role of reflection during tacit to explicit knowledge conversion. In seeking advice from others Mr A was converting tacit knowledge on farm processes into an ICT-compatible explicit form. Near the conclusion of the study Mr A also drew learning motivation from the new and enthusiastic farm worker. He was able to exchange ideas with the worker and also justify the reasons behind his *ICT-1* use, which promoted the reflective process and forced examination of differences between his espoused theories and theories-in-use (Argyris & Schön 1974).

### 4.2.4 Emergent learning

Several key themes arose in the emergence of a precision dairy farming system as Mr A sought to integrate *ICT-1* into his management practice. These themes centred on the struggle between self-learning and time management, the role that credibility plays in farmer acceptance of ICT trainers, and the role of effective networks.

The retailer’s use of a self-learning model fitted well with Mr A’s computer competency but not with his time management priorities. Dairy farmers are commonly described as time-poor, with milking and operational management tasks accounting for much of the daily routine. Any competing demands for time must be proven sufficiently beneficial to a farmer, and use of ICT in management is no exception. Learning support for ICT not only needs to build a base set of skills but also engender an awareness of the potential extended applications of the technology. Companies retailing dairy ICT currently place the burden of learning onto the user, helping build a base knowledge but then taking a ‘we’re here if you need us’ approach. For this approach to result in advanced utilisation, farmers must have an awareness of not only where the technology fits into their specific management system, but also how to realise the potential uses in a time-efficient
manner. In the face of competing time demands, Mr A deferred investment in his own learning until a respected outsider, *Trainer-1b*, mapped out the benefits of using more advanced functions. An example was the demonstration of automated use of conductivity for mastitis detection, highlighting the pathway to implement this change, and incorporation of the change into the farm management system.

*Trainer-1b* introduced a mix of farmer ‘know-how’ and ICT skills. In effect he was able to translate between the potential of *ICT-1* and Mr A’s specific requirements. Prior to his involvement, this link between ICT potential and on-farm use was weaker: Mr A had limited core knowledge of *ICT-1*, and *Trainer-1a* lacked core knowledge of dairy farm operations. The situation can be viewed in terms of Nonaka’s (1994) theory of organisational knowledge creation, discussed in Chapter 3. The ability to transfer knowledge between an expert in farm management and an expert in ICT involves externalisation and internalisation, or the conversion between tacit and explicit knowledge forms. In this case, both Mr A and *Trainer-1a* possessed tacit knowledge which they had to convert to an explicit form in order to allow communication of meaning.

Australian PDF-ICT retailers currently support their products in a flexible but minimalist way, relying on users’ self reflection to advance the learning process. This approach has been driven by a historical role as dairy equipment supplier as opposed to ICT trainer, the cost of running a more comprehensive training program with only a small dairy ICT user base, and difficulties with the large distances separating clients. Potential improvements in the training approach therefore revolve around ensuring farmers have the necessary tools to undertake their own learning. As identified by Kilpatrick and Johns (1999) farmers tend to prefer training delivered by ‘credible facilitators’ and in this instance *Trainer-1b* engendered more credibility than *Trainer-1a*. The extra connection provided by *Trainer-1b*’s knowledge of dairy farm process enabled linkage of common dairy farm practice with the ICT functions. The importance of learning from a ‘network of known contacts’ (Kilpatrick & Johns 1999) was also highlighted by Mr A’s use of respected neighbours and staff for reflective learning. He also rejected other potential sources such as young farmers groups because he judged they were not operating at the level he aspired to.
The experiences of Mr A illustrate the progressive development of a precision dairy farming system. While self-learning was required to implement ICT-1, Mr A struggled with other time priorities. When a credible and effective support network began to build around him, for example Trainer-1b and a new staff member, Mr A began to find inspiration and direction for his use of the technology. A key feature of this developing network was that Mr A’s role in its formation was a passive one. He did not actively seek out the network and its formation emerged serendipitously.

4.3 Mr B - Learning impacted by unmet expectations

4.3.1 Case description

Mr B ran a dairy farm in Gippsland, Victoria, in a partnership arrangement with his parents. He was primarily responsible for management, supported by his mother, and two fulltime staff. His father worked in the dairy industry in Melbourne during the week and helped out on the farm on weekends. Now in his late thirties, Mr B completed higher school certificate at secondary school, a four year dairy apprenticeship, and a Diploma in Applied Science (Farm Management). After a personal review of the farm’s future, Mr B decided to build herd size, adopting a ‘get big or get out’ philosophy. Farm goals included achieving a 25 percent improvement in pasture growth and utilisation, milking 500 cows year-round within two years, having cows at condition score 5 to 5.5, milking three times per day year-round, and increase effective milking area to 90 ha.

At the start of the case study in 2005, the farm had a very high stocking rate with a peak of 440 Friesian cows milked on 80 ha (5.5 cows/ha) in 2005 with an additional 32 ha of irrigated land used for dry cows. Because of the high stocking rate, production was dependant on purchased feeds with cows receiving 5 kg wheat, 2 kg lupins, and 1 kg canola per day on average during milking, while conserved fodder was also offered after milking via a feedpad. A split calving pattern (August and March) was used with calf rearing contracted out. Mr B had
previously experimented with milking three times per day to raise yield from fresh cows during the spring period.

Nutritional advice was sourced from a feed company consultant but at the time of the first visit he had been replaced with a new local consultant. Mr B commented that in general he found it difficult to find the time to seek new knowledge although he looks to high per cow producers in the industry, both in Australia and overseas, for inspiration.

4.3.2 Significant events

In 2005, Mr B invested in a new 50-unit rotary dairy shed to replace an aging 22-unit swingover herringbone dairy shed, taking the opportunity to install an ICT-2 system with collar EID, milk meters, ACRs, auto drafting, individual feedings, and auto teat spray at the same time. Software was loaded on a computer in the dairy shed office a short walk from the cups-on position. There was no history of herd management ICT use on this farm, with hardcopy herd records primarily used and limited use of computers for word processing, email, and internet. Several setbacks occurred during installation of ICT-2 and its subsequent incorporation into the farm management system, and this case reveals the importance of user expectations, the user-provider relationship, and confidence in the data collected.

The ICT-2 system was purchased with the key goal of increasing milk production through individual feeding. Consequent herd management improvement was viewed as a secondary goal with Mr B identifying milk yield variation as potentially useful in diagnosing cow health issues such as mastitis and metabolic problems. He did not expect ICT-2 to entirely replace tacit herd management processes stating ‘it’s not going to be as good as Mum’s eye, but it’ll be similar’ (Mr B, August 2005). Mr B’s initial philosophy signified ICT-2’s role as an independent tool focussed on feeding to production, rather than a system that could be fully integrated into farm management.

Mr B had high expectations of the collar transponder component of ICT-2. In particular, he expected high accuracy of electronic identification, based on pre-sale
discussions with ICT-2 salespeople and current dairy ICT users. He had investigated EID based on the National Livestock Identification System (NLIS) eartag, but heard that misreads could be as high as 10 percent and judged the potential implications for feed misallocation to be unacceptable. Near-perfect accuracy was predicted by ICT-2 salespeople, a claim not supported in conversations between Mr B and other users who reported EID malfunctions and teething problems that took up to six months to remedy.

‘If you listen to them (ICT-2 salespeople) it’s going to be absolutely perfect, but then talking to a couple of other farmers before we signed up for them they have the odd transponder that breaks’ (Mr B, August 2005)

Auto-drafting was also expected to improve upon the estimated 95% accuracy of manual drafting achieved in the old dairy. Potential EID inaccuracies led Mr B to adopt a cautious mindset regarding initial use of individual cow data.

Mr B anticipated a learning challenge with the new software and adapting milking routines. He planned to seek advice from his consultant, or adopt a trial and error routine, when adjusting an alert threshold. An example of the trial and error strategy involved adjustments to the threshold level where a change in seven-day average milk yield triggered the ICT system to auto-draft cows. Mr B stated that he would determine the appropriate threshold sensitivity through observing the number of ‘false positive’ cows drafted. If the threshold was set to auto-draft cows with a milk yield less than 90 percent of their seven-day average and subsequently resulted in too many healthy cows being auto-drafted, Mr B would adjust the threshold until he was happy with the sensitivity.

The new rotary dairy was first used in September 2005 and blanket feeding was used for the first five weeks after installation while cow details were entered and initial milk yield data were collected. Individual feeding, based on seven-day rolling average milk yield, was enabled in October 2005 and continued for five months before it was discovered that a software glitch was leading to feed being dropped in the wrong bail. A software upgrade in February 2006 overcame the issue. EID misreads experienced in the first 6 months of ICT-2 operation also led to
inaccurate milk yield data and misplaced feed, and the supplier installed six ’confirmation EID readers’ throughout the platform in early February 2006. By March, 98 percent of cows were being identified correctly by the ICT-2 system. Persistent problems resulted in the highline system being converted to a low line and a secondary EID sensor being installed in May 2006 near the cups-on position. The ICT-2 supplier eventually employed an independent expert to help fix problems with the new rotary, which were not all related specifically to the ICT system. In addition the warranty period was not activated.

The relationship between Mr B and the ICT-2 supplier deteriorated due to differing opinions over the reason behind EID inaccuracies and other glitches. Mr B described the supplier’s responsiveness to the problems as inadequate, with no service provided from September 2005 through to January 2006. In an effort to resolve this, Mr B threatened a solicitor’s letter in January 2006 and later emailed his concerns to the Australian, Oceania and International head offices. Throughout the process Mr B felt that the company’s first response to problems was to blame operator error instead of taking his concerns seriously.

‘I have actually got very little respect from them (ICT-2 supplier) because I am actually telling them that their system’s not working properly, therefore their first thought I think is it’s human error and then they pick on my operators, my employees, as well.’ (Mr B, September 2006)

According to Mr B there was insufficient communication from the supplier about what they planned to do to address the problems, and when they did visit the farm Mr B would have appreciated more feedback on what actions were actually undertaken. A disconnect also emerged between local service agents and head office technicians.

‘The (ICT-2) service has been absolutely shocking from head office…the local service agent, I get along with him reasonably well, there’s a good relationship there, not a problem.’ (Mr B, March 2006)
While his relationship was good with the local agent, Mr B felt the agent didn’t possess the skills necessary to identify and solve ICT-2 problems. In comparison, the head office technicians were able to offer quality advice on the ICT system but were difficult to get to the farm and Mr B felt they were too dismissive of his concerns.

In the first year of ICT-2 operation, the herd experienced unprecedented health and production problems, central to which was an incidence of acidosis across the herd in late 2005. In spring 2005, fresh cows peaked approximately 5 litres per day lower and consequently averaged 6800 litres for the season instead of the 8000 litres per cow expected. Conception rates fell dramatically and 100 cows, one third of the spring calvers, had to be carried over for 15 months due to infertility. While Mr B attributed these problems to faults in the EID and feeding system, he also believed that incorrect vacuum pressure was responsible for increased teat problems in the herd. Mr B acknowledged that some acidosis occurred after grain was not crushed due to incorrect crusher maintenance he performed. Somatic cell count rose from 300,000 cells/ml to 500,000 cells/ml and Mr B stated that since using the new dairy he had ‘culled more cows for sore teats and temperament than in the last 25yrs’. Mr B adapted his farm management to account for the health and production issues, moving to a 50:50 calving pattern, placing an extra emphasis on nutrition to correct the acidosis concerns and maintain yields in the carryover cows, adopting a more aggressive culling policy for cows that dried off early, and purchasing 45 extra fresh cows to maintain milk volume through the autumn 2006 period.

Initial ICT-2 training was provided at installation (August 2005) with additional one-on-one training in early December 2005 from Trainer-2a, an experienced farmer-user contracted by the company to provide software training. The ICT-2 supplier indicated that a group training session would also be organised but Mr B was not aware of any being run during the course of this case study. Ad hoc training occurred via Mr B asking software related questions when technicians visited the property to address other issues. Mr B found he learnt more about ICT-2 by ‘playing with it’ or receiving advice on specific issues, as opposed to dedicated training sessions. In September 2006 two company technicians conducted further
training and concentrated on areas such as report creation and using groups to manage cows, but Mr B felt his knowledge of the system was not greatly enhanced.

The training provided by off-farm sources, and internally by Mr B himself, neglected Mr B’s mother, a vital cog in the farms information management. After installation, Mr B contracted a person to enter basic cow information into the ICT-2 database but his mother had the ongoing role of data management. With limited previous computer experience, she was comfortable using word processing and internet software but not confident with other functions such as email. She was not present for service provider training sessions but Mr B found these demanding and thought they would have had limited benefit for his mother.

‘(Trainer-2a) came down and spoke too fast and showed things too quickly, my mother wouldn't have had a chance to pick up on anything he said if she was around, fortunately she wasn't.’ (Mr B, September 2006)

Prior to installation, Mr B acknowledged that he had a role in training his mother but during the case study period she developed only basic ICT-2 understanding. As a result hard copy records were still widely used and the database entry was limited and not always up-to-date as discussed below.

The impacts of technical problems, the service provider-user relationship, and training programme on information and risk management are illustrated in the following examples.

**Information management**

Installation of the ICT-2 software presented an opportunity for more efficient and accurate herd management on Mr B’s farm. Historically, herd test results were used to assess cows for production however no herd testing had been carried out since early 2005 with milk yields obtained via ICT-2 and daily herd fat, protein, and SCC obtained from the milk company vat testing programme. Previous herd information management was based around hardcopy records of calving details (date of calving, cow number, calf number, sire) and milk company quality
assurance recording (medical records, incident records, milking roster). More recently cow mating details had been entered into a word processing file by Mr B’s mother and then printed off and used at the dairy to mark off pregnant cows. Most of these manual processes remained after the installation of ICT-2. Only basic data were entered into the database, including data required for system functionality (calving dates and dry off dates), insemination dates, pregnancy status, and calving details (ease of calving, sex). ICT-2 will only recognise and feed a cow in the dairy if she is in the milking herd and this provides an incentive for Mr B to promptly add calving dates. Other details are not added in such a timely fashion.

‘Some cows I’ll go to calve and go oops, I haven’t dried her off yet, but realistically the system is not performing that well yet anyway, the crunch of the matter what you want out of the system is to accurately feed cows, anything else you get’s a bonus really.’ (Mr B, September 2006)

Risk management processes
Low confidence in ICT-2 operation forced Mr B to implement risk management processes. EID accuracy problems meant little use was made of computerised ‘don’t milk’ alerts for cows treated with antibiotics or having mastitis issues, and back-up systems such as leg tape were still used. Fresh cows were milked with the physically separate ‘hospital’ herd in case they were not entered accurately into the database. During milking, the cups-on operator monitors the cow number on the screen display and if an error is noticed the correct cow ID can be typed in. Older cows in the herd have freeze brands on their rump where they cannot be seen from the cups-on position therefore Mr B plans to re-brand cows on their leg. During the first few months of system operation Mr B switched the feeding back to manual due to the misreads and the risk that cows were not being fed appropriately. He also started entering cow data directly via the processor box instead of using the windows-based GUI after several instances of incorrect data entry.
4.3.3 Critical issues

Utilisation of the wider functionality of ICT-2 on this farm was limited by issues of unrealised expectations, low trust in the system, and communication breakdowns with service providers. As a result the learning process differed markedly from that observed on other case study farms and provided an insight into ICT learning in the face of technical deficiencies and low system confidence.

Mr B openly sought to learn from the experiences of others, both in regard to ICT and in general farm management. Reliance on other people for information rather than on their own analytical ability is a feature of Kolb’s (1984) ‘accommodator’ type, which matched Mr B’s learning style. An example of Mr B learning from others was reviewing ICT-2 users experiences to guide his purchase decision and to develop expectations for use. In terms of farm management, he sought inspiration and information from outsiders whom he considered had something to offer his operation, such as farmers with high producing herds or nutrition consultants. He also looked to ‘knowledgeable others’ when faced with specific problems such as an independent dairy technology consultant to review performance of the new dairy, and an acquaintance skilled in ICT to investigate adaptation of ICT-2.

Mr B also exhibited accommodator characteristics in his risk-taking and intuitive trial-and-error management style. This style does not appear to sit well with the structured and regular data entry required for successful dairy ICT use and responsibility for ICT-2 maintenance may have been a more appropriate fit with Mr B’s mother or another staff member. Significant training was required to provide Mr B’s mother with the skills and confidence to use ICT-2. Training of a staff member was inhibited by staff turnover rates and consequent uncertainty over long term benefits from such a training investment.

The overall learning support package appeared to be less effective compared to other farms in the study, highlighted by Mr B’s limited integration of ICT into his management. Formal contact time was comparable to the other ICT-2 users but it lacked flexibility to account for the specific characteristics of this case. The input and maintenance of key cow data needed to be fostered but was held back by Mr
B’s management style and his mother’s inexperience and low confidence with computers. An alternative approach would have been for a technician to work with Mr B’s mother to help her understand the basics, and provide an easy to understand guide to the basics.

The original ICT-2 goals and performance expectations had a major impact on eventual utilisation and satisfaction, highlighting the need for dairy ICT retailers to pay special attention to these factors in the pre-sale stage. Differing expectations of EID accuracy were highlighted between Mr B and the retailer, as outlined by Mr B.

“They think it’s roughly fixed when it’s working 95% accurate, I would like those extra 3-4%.” (Mr B, September 2006)

While he acknowledged that 100 percent accuracy was not possible, and that 98 percent was acceptable, he was less comfortable with the realisation that 2 percent error in a herd of 500 cows translates to 10 cows per milking being wrongly identified and fed. The ability to feed cows a consistent and individual ration was Mr B’s primary investment hence his frustration was raised when the ICT-2 system didn’t perform to the standards he expected. Consequent loss of trust in both the milking data collected and EID accuracy further diminished any enthusiasm Mr B had to spend time entering non-essential data into the computer and to invest time extending his learning.

Communication breakdown between Mr B and the retailer occurred on several different levels. Mr B felt his concerns over inaccuracy of the ICT-2 system were not accepted by the head office technicians, and when modifications were made he felt uninformed about the technician’s diagnosis of the problem and how it had been resolved. This excluded Mr B from the process, and prevented him from learning how to diagnose and solve similar issues in the future. It also suggested to Mr B that the company was trying to avoid admitting to faults in the system.
4.3.4 Emergent learning

The emergence of a functional precision dairy farming system in Mr B’s operation was impacted by misaligned expectations between buyer and seller in terms of both performance and learning requirements. Also evident was the suppressed development of a learning network due to friction between Mr B and the retailer, and due to Mr B’s independent management style. The experiences of Mr B provide a valuable insight into factors that may impact the successful achievement of precision dairy farming goals.

In the pre-sale stage there should be explicit communication between the salesperson and potential buyer regarding goals and expectations of the ICT system. The salesperson understandably wishes to make a sale as these installations are generally worth in excess of AU$100,000. However, possible problems post installation, such as occurred on this farm, can quickly erode a retailer’s profit margin due to extra technician visits and technology refits. Promotion of dairy ICT systems as a management tool needs to take end-user goals into account and to highlight limitations of the technology as well as the benefits. Dairy ICT retailers also perceive their systems to be ‘plug and play’, whereas this case study highlighted the level of technical problems that may be faced between installation and operation at a level acceptable to the user. Strict timelines for changeover between the old and new dairy can often lead to cows being milked in a system that has not been fully tested.

Users have little incentive to invest time into learning a system that they do not trust. In this case Mr B did not trust the accuracy of the data collected or that he could rely on the technology to carry out tasks to the required standard, for example accurately identifying cows treated with antibiotics. In addition, the relationship between himself and the retailer deteriorated to an extent where he did not trust that they were actively addressing his concerns. He felt they first assumed the problem was with him, not the technology. More explicit action from the retailer would have helped to include Mr B in the process, and minimise communication breakdown. Examples of this include providing the farmer with records of what was done during technician visits, and statements of the retailer perspective on reasons for the technical problems.
Mr B’s learning style, highly focussed on assimilation of others’ knowledge and application of that knowledge in a trial-and-error fashion, conflicted with structured ICT support offered by the retailer. Mr B often sought information from people he considered to be credible sources, a common feature of farmer learning (Kilpatrick & Johns 1999). The relationship between Mr B and ICT-2 technicians undermined Mr B’s perception of their credibility, and therefore it diminished the value he placed on the advice they provided.

Tacit knowledge formed the foundation of Mr B’s management style. He is adept at memorising facts and figures, both from experience of his own operation and from discussion with others. ICT depends on explicit knowledge, and therefore farm management practice needs to be externalised into a form compatible with the deterministic nature of decision support systems. The conversion of tacit to explicit knowledge in this case was impeded by lack of reflective practice. While Mr B could identify general critical success factors in his operation verbally, there was little evidence of a double-loop learning process whereby these factors could be fine-tuned and made explicit enough to match the binary parameter based operation of ICT-2.

This case highlighted potential incompatibility of a farmer’s learning and management styles with the explicit and structured nature of ICT and ICT support. In addition to including explicit discussions over expected technical performance of new dairy ICT installations as recommended above, the pre-sale process should address learning requirements and expectations. This could be based around a form of learning contract where expectations on both sides are noted. Users will naturally be interested in the level of support provided, how many on-farm visits, who to ring if something goes wrong, how many months or years support is provided and what the cost will be. Just as importantly are the retailer’s expectations. Implicit in the sale contract is an expectation that the user will engage in self-learning, and that the role of an ICT technician is to support the learning process rather than be a constant technical resource.
The implementation of ICT-2 in Mr B’s operation illustrates the need for a more explicit ‘learning contract’ between the buyer and seller. Such a contract could include specific performance indicators against which both sides track their progress. For example, if a buyer thought an undertaking to provide on-farm training or user group sessions was not fulfilled he would have recourse to dispute the level of support. Conversely, if the retailer offered training such as user groups which were not attended by the buyer it could be used as a justification for refusing extended product support. In Mr B’s case the contract could have outlined a specific ICT role for Mr B’s mother and the training support required to supply her with sufficient ICT skills. A contract outlining learning expectations brings the farmer into the learning process, specifically acknowledging their personal responsibility to invest time and effort into ICT learning. Thus farmers are less likely to avoid their learning responsibilities and the expectations of both sides are more transparent.

This case study farm provides an insight into how the development of a functional precision dairy farming system can become stalled. Mr B’s learning was obviously hampered by unmet expectations, but it was the failure to form an effective network around the material technology that held back system integration and use. Potential members of the network did not link together, either due to an atmosphere of conflict, a lack of delegation of ICT tasks, or unaddressed deficits in appropriate ICT skills. The missed opportunities for linkages and therefore co-development of the precision dairy farming system resulted in a highly under-utilised system.

4.4 Mr C and Mrs C - Immersion in information

4.4.1 Case description

Mr and Mrs C sharemilked on a third generation dairy farm owned by Mr C’s parents in north-east New South Wales. Farm ownership was in a transition phase with Mr C’s parents looking to ease out of operational involvement as Mr and Mrs C progressively bought into the business. Day-to-day management was shared
between the couple and Mr C’s father with an additional person employed 25 hours/week for general farm work and occasional milkings. Mr and Mrs C were in their thirties with two children. Mr C completed a dairy apprenticeship after leaving school and Mrs C had a dairy farming background and had completed a rural traineeship. Their five year farm goals included increasing per cow production to achieve 1.5 million litres from the same number of cows while producing milk at lower cost and with less labour.

In 2005, a peak of 175 Holstein-Friesian cows were milked on 200 ha of subtropical and annual ryegrass pastures, of which only 140 ha was productive during wet periods giving a stocking rate of 1.1 cows/ha. A separate 40 ha was used for heifers and replacement stock. The cows were calved in a year-round pattern and per cow production was 8300 litres in 2005, high in comparison to the national average of 5,163 litres/cow (Dairy Australia 2007). Grain was used to maintain production levels with up to 10 kg/cow/day fed in the dairy. Mr and Mrs C focussed on conserving fodder as silage or hay in order to minimise spending on purchased feeds and to provide income through sales.

4.4.2 Significant events

A 14-aside swingover dairy shed was retrofitted in late September 2005 with an ICT-2 system that included NLIS tag-based EID, milk meters, ACRs, and individual feeding. Data are fed into ICT-2 software on a computer in a converted office near the vat room. In mid-2006, a Palm™ unit with ICT-2 software was purchased to enable data collection in the field, and in November 2006 a standalone ICT-2 compatible somatic cell meter was added to the ICT system. The decision to purchase a somatic cell meter was based on a goal of identifying cows which were impacting on the farms premium milk quality rating. Mr and Mrs C were the driving force behind purchasing and operating ICT-2 and expressed determination to get a return on their investment. Their main goal was to enhance feeding efficiency and consistency, while also gaining labour savings in the shed and improving heat detection. The purchase of ICT-2 system components was highly goal orientated to minimise capital investment. Extensive use of data in herd management, outlined below, resulted from this focus on achieving a return on investment.
Cost and ease of calibration were key factors in the selection of milk meters based on milk weight measurement rather than the more accurate infrared-based technology. Combining entry level milk meters with NLIS-based EID provided a lower cost but potentially lower accuracy. Mr and Mrs C were comfortable with this accuracy trade-off however they did have pre-installation expectations for ICT-2 operation in the areas of learning and usefulness/ease of use. In terms of learning, they expected to become proficient users within six months of installation. The retailer assured direct upload of herd test data into ICT-2.

Mr C relies primarily on the tacit knowledge gained by himself and his father during their dairying experience. Limited information is obtained from off-farm sources such as veterinarians or feed company nutritionists. Herd management software had not previously been used on this farm, with herd testing results viewed in either hard copy form or in spreadsheets received by email. Mrs C was responsible for maintenance of farm financial data, heifer records, and registrations, which were recorded in MS Excel™ spreadsheets. Mrs C was comfortable with using a computer while Mr C had negligible computer experience. The primary role of ICT-2 data management therefore fell to Mrs C and Mr C faced a steep learning challenge. Initially he relied heavily on his wife for IT support, for example ringing her from the dairy office to ask questions about entering data or sourcing cow details. Mr C’s father was mildly negative toward the new technology initially and struggled with changing over from the previous milking routines. His interaction with ICT-2 was limited to milking time which was made as easy as possible using simple operational flow-charts, and basic tips listed on a whiteboard, visible from the pit.

The sales package included 2-3 days of one-on-one training, 24-hour phone support, limited free software upgrades, and attendance at one or two user groups per year. Training delivered during the case study period included a start-up session at installation, a one-day on-farm training session run by Trainer-2a (a farmer used as a consultant by the company) after 3 months, and a user group attended by Mrs C seven months after installation. The ICT-2 retailer was planning a more advanced user group but this did not occur during the case study. Mrs C
said the initial training at installation was very basic. She was shown how to enter data critical to making *ICT-2* operational (cow number, date of birth, and calving date) along with advice on setting up feed tables. Most contact time with technicians was concerned with fixing minor problems rather than training but they did watch and learn from the technician’s use of *ICT-2*.

In other farming businesses, this amount of training might have been inadequate, but Mrs C’s utilisation blossomed through dependence on self learning and a desire to maximise the benefits from *ICT-2*.

‘As far as the computer I have found it easy to pick up, learn what to do, I suppose I kept on track of everything, if you don’t use it regularly you are not going to get the right benefit out of it.’ (Mrs C, February 2006)

In the initial four months, Mrs C’s interaction with the software mostly involved looking at the data being collected. It was over the next four months that she began to turn the data into information through creation of specific reports and filters. After this four month early learning phase, Mrs C consolidated her knowledge by concentrating on her key reports rather than adding new ones. Her learning process matched the three phases discussed in Chapter 2 of early learning, consolidation, and advanced learning. Trainer-2a had an influence, teaching her how to enter data via batch entries to save time and his visit to some extent helped spur Mrs C into greater utilisation of reporting functions. By the time she attended the ICT-2 user group, Mrs C’s learning curve had flattened off again, and she found herself the most advanced user in the group, even though others had been using the system for up to two years. Consequently, she learnt few new skills from the day. In her opinion the other farmers had not put enough effort into self learning.

‘From the sounds of them, they hadn’t sat down and down a lot of fiddling with it, whereas I thought you buy a program you’ve got to figure out how to use it so I just sat down and fiddled with it. With the different reports and different areas, it’s what you’ve got to do.’ (Mrs C, November 2006)
Mrs C’s knowledge of ICT-2 advanced to a level where the retailer was asking her to become a training consultant to other users in the region.

Changing from tacit to explicit knowledge
There was a distinct and rapid change from using intuitive, tacit-based decision processes to use of more timely and objective explicit knowledge (Box 4.1). Within two weeks of ICT-2 installation, Mrs C had created a temporary report to aid a one-off culling decision based on milk production, days in milk, and pregnancy status. ICT-2 was used on an operational basis with cows listed for culling if they were non-pregnant and producing below 10 litres/day, or if they had severe health problems. Twelve months after installation, Mrs C created a daily updated report listing cows producing less than 15 litres per day, which was used to drive culling and dry-off decision making. This report marked a change to more proactive management compared to previous culling decisions based on visual assessment of health problems, or milk yield and SCC factors derived from herd test figures, which might have indicated problems present for weeks. The impact on management was significant. By making it easy to identify low yielding cows, a major culling program was undertaken, as explained below.

‘There is probably 40 head gone out of the herd since we put the system in, in the six months. Some of them had to go anyhow, but the system has brought on some going quicker because they weren’t milking as well as you probably thought they were.’ (Mr C, February 2006)

‘(Previously) you might take a lot longer to decide whereas now you’ve got all the information there, you can say she hasn’t been mated, she’s been in this long, she’s only got so many litres, just decide to get rid of her.’ (Mr C, February 2006)

Individual feeding rations were previously determined through visual assessment of Mr C or his father, with minor monthly corrections based on herd test results, and delivered via a pull-cord to drop feed. Potential inefficiency arose from subjective milk yield estimation based on udder size, personal favouritism, poor
feeder calibration, and cows learning to feed themselves via the pull-cord. Under ICT-2 cows, are fed based on their rolling 7-day average milk yield.

**Box 4.1: Use of ICT-2 by Mr and Mrs C for operational and tactical management**

<table>
<thead>
<tr>
<th><strong>Milking alerts</strong></th>
<th>Low milk, heat predicted, treated cows</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Special reports</strong></td>
<td>Herd test day</td>
</tr>
<tr>
<td></td>
<td>Herd test printout to advise herd testing centre of cow production and milking order along with those they don’t want included in this months test (fresh or sick cows)</td>
</tr>
<tr>
<td></td>
<td><em>(Stall position at milking, calving date, morning and afternoon milk yield, 7-day milk yield, cow name, Herd test number, birth date)</em></td>
</tr>
</tbody>
</table>

**Daily reports**

- Management groups
  - Herd broken into 12 virtual groups based on age and stage of lactation. Used for comparison, see how many heifers there are, how many dry cows are in the paddock

- Cows due for insemination
  - Identifies cows over 75 days in milk but not yet on heat and helps in select those for vet to check for prostaglandin use

- Calving due

- Milk reports (see who are the low producers and examine possible reasons)

- Culled/Dried off report

**Adapting management routines to include ICT**

A key to the integration of ICT on this farm was the development of a structured approach to managing data. After morning milking Mr or Mrs C spent 5-10 minutes to check low milk alerts, and enter data such as joinings, heats or treatments. They also adapted their routine to check milk production and milking performance looking for misreads which they would fix straight away, and check the time taken for milking. This commitment led to an up-to-date and comprehensive database valuable for decision making. Mrs C set up standardised options for employee and technician names, possible reasons for culling, reasons for death, calving notes, drugs used, and health notes. When a cow calved, received medical attention, had a pregnancy test, or was mated, dried off, or culled, the details were entered into the system using the standardised terminology. The risk of errors was subsequently minimised and the *ICT-2* database provided an in-depth cow history to the extent that milk company quality assurance assessment is now entirely *ICT-2* based.
Up to 30 minutes per week was spent by Mrs C reviewing data, comparing between groups of cows and looking for anomalies. Finding time to do this was made easier by having a second computer at the house to which data were transferred by USB memory stick. While the computer in the dairy office served as a database and entry point for daily data, the house computer was available for Mrs C to use in her own time for tactical decision making whilst also staying close to the children.

Mr and Mrs C also learned through experience to incorporate quality management structures into their daily routine. A feed system glitch in the first 10 days of operation made Mr C more aware of potential issues with feed calibration. He learnt to assess changes in density of new grain mixes delivered to the farm and would carry out a calibration test if he suspected a possible issue for the volume-based auger feeders. Experiences with EID misreads led them to be more vigilant during milking for incorrectly identified cows, and they also conducted daily post-milking reviews of data in the ICT-2 software to look for EID mistakes. This process facilitated immediate correction of errors while still fresh in their minds, but was relatively easy in their small herd operation. Another example of learning experiences driving adapted management was a problem encountered with ICT-2 individual cow milk yield confirmation during milking. If the cups were shifted to the next cow without the swingarm being properly moved past a switch then ICT-2 would not recognise the closure of the previous milking session and the next cow’s milk would be attributed to the previous cow. After identifying such instances in the milk records and finding the cause from ICT-2 technicians, Mr C introduced a ‘swing and wait’ milking routine to ensure correct swingarm placement prior to fitting cups.

4.4.3 Critical issues

Introduction of dairy ICT induced a marked shift from tacit to explicit management on this farm along with more timely and objective decision making. The ease of learning and level of integration of ICT into farm management stands out amongst the farms studied in this project, and in comparison to other ICT-2 users in the
same region. What are the factors that facilitated this level of uptake and resulted in ICT-2 becoming a focal point for decision making rather than just another tool? Mrs C is obviously a key factor; she had prior computing skills, was not required to be out on the farm all day, and along with Mr C possessed a drive to get the most out of the investment. Another factor was investing with tight goals and not over capitalising.

As ICT learners, Mr and Mrs C were very different from each other and they recognised these differences and designed their roles and responsibilities accordingly. In the learning styles exercise (Kolb 1984) Mrs C was a diverger while Mr C was an assimilator. According to Jagdev et al. (2004) this indicated that Mrs C might approach problems with an imaginative mindset, while Mr C would prefer to review information that was already in an organised form. Mr C admitted to a low familiarity with computers and was happy to leave more advanced data analysis to his wife, but he was still able to progress his personal learning to a stage where he comfortably entered data after each milking. Mrs C received similar training to other case study farmers but differed in the amount of self learning she undertook between formal training sessions. This highlights the reliance of dairy ICT training programmes on a positive self learning attitude from users. Mrs C believed that people with less computer skills would need more training than she was offered, including a 12 month minimum support period with courses every 4 to 6 months because it was a lot easier to learn if there were people to demonstrate ICT functions.

Another vital factor was the managerial connection between Mrs and Mr C. Although she was not always present at milking time or out in the paddock, communication between husband and wife was such that Mrs C could use ICT-2 confident that she was up-to-date with daily management issues. In a study of computer use on Australian farms Bryant (2003) found that men acted as ‘gatekeepers of information and knowledge’ while women attempted to use ‘their greater IT skill to access information and participate as equal business partners’. However, gender divisions of labour were retained even after installation of IT because women retained their role as record keepers with men taking responsibility for analysis and planning. Bryant (2003, p.470) stated that:
Very few farming households work collaboratively to enter, access, interpret, and use information for farm business management from information technology systems.’

Mrs C’s leading involvement in the use of ICT-2 certainly supports Bryant’s assertion that farming women tend to have greater IT skill. However, this farm is an example of a farming household working together to share knowledge and link it with information technology. The reasons this was achieved are discussed further in the emergent learning section.

Mrs C had a vested interest in maintaining accurate data input, and had the trust of Mr C. On farms where a non-family employee is made responsible, this level of connection and trust could be more difficult to achieve. There is less opportunity to sit down over the breakfast or dinner table and discuss the day’s activities, and it could be difficult to trust employees to be as careful as a farm owner in ensuring antibiotic treated milk does not reach the vat.

Limited financial resources and a focus on realising a return on the ICT investment meant Mr and Mrs C designed the ICT-2 system to fulfil their specific goals around feeding and labour efficiency. Non-essential components such as activity sensors, conductivity, and auto drafting were not purchased, in effect simplifying data analysis and minimising learning associated with interpretation of activity and conductivity data. By collecting milk yield data and complementing it with information on animal health and breeding, the subsequent options for data analysis were narrowed and the pathway to achieving benefits from the data was clearer. The key benefits for Mr and Mrs C were efficient grain feeding, minimised herd testing costs, and labour savings.

4.4.4 Emergent learning

This farm illustrated the development of a precision dairy farming system in complete contrast to that observed in Mr B’s case. The emergent themes which help explain this difference centre around Mr and Mrs C’s ability to self-learn, the focus on role delineation, use of a modular capital investment strategy, and the adaptation of farm management routines. An emergent learning analysis also illustrates the existence of ‘core competencies’ – facets of ICT use in which
farmers require certain capability in order for them to develop a functional precision dairy farming system.

Dairy ICT training programs currently rely heavily on self learning from the user. In this farm the approach worked successfully because it matched well with the specific circumstances and personnel. Mrs C was willing and able to focus her attention on ICT utilisation, whereas on larger farms with greater time demands on staff, and less connectivity between the ICT user and overall farm management, such high levels of use may not have been achieved.

Delineation of data entry and analysis responsibilities provided structure and certainty in ICT use on this farm. The question of who will use the ICT system and what their respective roles will be should be considered in the pre-purchase stage. Retailers also have a role here in highlighting the importance of structured data entry and possibly grooming certain staff members for the role. Specifically allocating the role of data management to one person allows them to develop processes and familiarity with the software, however farmers are understandably reluctant to delegate or invest too much time in a worker who may move on from the farm, taking their ICT skills with them. On this farm the delineation of roles was obvious due to Mrs C’s affinity for computers and ability to allocate time to data management and system learning. Installing the software on the home computer allowed her to structure ICT use into her daily routine and to take ownership of developing processes such as regular database synchronisation and feed ration review.

Achieving a return on investment is a key aim of farmers adopting dairy ICT systems and integral to this is matching user goals to eventual investment. As with any technology, buyers can get caught up in owning the latest features, even when the add-ons have marginal benefits. On this farm each investment was carefully considered, in light of limited finances and a desire to achieve a real benefit. Add-ons such as the Palm™ unit and somatic cell (SC) meter were only purchased after a need was clearly identified. The other key factor in the focussed use of dairy ICT on this property was its smooth installation. Retro-fitting into the existing shed sidestepped distractions associated with learning to milk in a new shed and
allowed Mr and Mrs C to immediately begin integrating the ICT system into their management practice.

This farm presents an ideal case of successful ICT adaptation into the farm management routine. The experience of Mr and Mrs C shows the importance of aligning different ‘core competencies’ for learning which include not just aptitude with computers, but also the enthusiasm to use ICT and the ability to externalise management practice into an ICT compatible form (Figure 4.2). This is consistent with research by Streeter (1992) who found that successful users of IT systems had a specific level of human capital and were focussed on their information needs. Mrs C had sufficient ICT skills to immediately engage with ICT-2, but her ICT experience was not markedly different than users in other farms studied. Mr and Mrs C’s engagement with the new system set them apart from others, as they were highly focussed on utilising the newly acquired information and software. The key to creating a seamless link between day-to-day farm management practices and use of ICT as an active management tool was the ability of Mr and Mrs C to transfer knowledge between themselves and the database. Mrs C, the key ICT user, understood the business operation sufficiently to retrieve key data, such as cows in oestrus, from Mr C and enter them into the database. It is a testimony to Mr and Mrs C as a management team that information was able to flow in such a fashion. The Palm™ purchase further strengthened knowledge transfer by ensuring recording of field-based observations in an ICT-2 ‘synchronisable’ form.

**Figure 4.2:** Core farmer competencies for precision dairy farming system development
Insufficient focus by farmers and retailers on all three competencies in Figure 4.2 may inhibit the learning process. Sufficient computer skills without engagement in the new software could result in a solid base level of use but potentially poor employment of advanced features. Alternatively, having sufficient computer skills and being enthusiastically engaged with the ICT but with poor transfer of operational management data into the system will result in frustrations from incomplete or inaccurate datasets and lack of returns on the expended effort. The knowledge transfer learning level is especially important where the main ICT user is not the key decision-maker, or is not exposed to aspects of operational management. Mr and Mrs C bridged this divide and worked together to formulate use of ICT-2 which matched their decision-making requirements.

The success of ICT installation and use on this farm led to the unexpected emergence of a learning network. Impressed with Mrs C’s ICT-2 use, the retailer enlisted her to support other local users and discussed the possibility of formally contracting her as a regional ICT-2 trainer. As discussed previously with Trainer-1b, Mrs C has the ability to translate between the knowledge domains of ICT and specific dairy farming practice and therefore is a key resource for new learners. In dairy ICT learning networks a person who can bridge two knowledge domains carries even greater importance if they are local and accessible, in contrast to the retailer’s ICT technicians who often have training responsibilities across Australia and even into New Zealand. Locally based trainers can also engender greater credibility and greater potential to connect with farmers.

In conclusion, the events observed on this farm highlight key features for the successful development of a precision dairy farming system. As a management team Mr and Mrs C were strong in the three core competencies of skills, engagement, and knowledge transfer, needed for successful use of dairy ICT. In addition they settled into delineated roles with regard to data entry and analysis, making best use of their respective skills and time demands. Adapting their management routine was made easier by Mr and Mrs C’s decision to invest in ICT in a modular fashion. This approach ensured a return on investment was achieved, in addition to allowing them to focus on developing skills and confidence with use.
of one module of the technology before investing in another. Success in adapting to a precision dairy farming system came from knowing what they wanted to achieve from the system and putting effort into realising it.

4.5 Mr D - Controlling the complexity

4.5.1 Case description

Mr D had farmed his Gippsland, Victoria, property for 30 years. Due to participation on dairy industry boards Mr D spent a significant amount of time off-farm and employed a herd manager in addition to approximately 10 full-time equivalent employees. Born on a dairy farm, Mr D also had experience with beef production and working in non-farming industries. He built up the current property initially through sharemilking. A highly analytical farmer, he sourced information from field days, email discussion groups, consultants, and magazines and had also completed a Nuffield Scholarship.

The large operation milked 900 cows producing 8600 litres/cow/yr on 330 ha (2.7 cows/ha) in a split calving pattern (75 percent March: 25 percent August). An additional 270 ha of leased runoff was used for dry stock and forage production. Four physically separate herds were run to minimise pressure on the feed pad and time spent off the pasture. The four herds were divided into stale cows, heifers, fresh cows, and sick cows. The business was highly geared to achieving premium milk prices by exploiting seasonal and quality price incentives. Farm goals included achieving 1100 cows milking 9,000 litres. The herd was at a steady stage in terms of cow numbers and the focus was on increasing per cow production and raising milk protein levels through better nutrition.

Computer software use on the farm, or via a service provider, dated back to 1981 including use of MS Excel™ (ration calculation, staff roster), MYOB™ (finances), nutrition programmes, ‘Dairy Data’ (1995-present), and ‘OnFarm’ from 1997-2005. Mr D was one of the first to use the locally designed ‘OnFarm’ EID-based herd management system, essentially beta-testing the system. Data were double
entered into Dairy Data and OnFarm because of their strengths in herd health and operational herd management respectively. Monthly herd testing provided data on individual cows that were directly uploaded into the OnFarm software.

### 4.5.2 Significant events

In June 2005 the existing 12 year old 60 bail rotary dairy was retrofitted with NLIS-based EID, milk meters with conductivity, auto drafting, automatic cup removers (ACRs), auto teat spray, and four feed head individual feeding capability. The system was administered by *ICT-1* software loaded on a computer located beside the rotary platform itself, rather than in a separate office. The goal for the new ICT system was to simplify herd management and increase labour efficiency in this large and complex dairy business. Mr D wanted to use milk yield and conductivity data to identify cows operating outside average parameters in terms of production and health.

’Instead of having a herd of 900 cows, we want to have 900 herds of one cow. And you want to be able to do it simply and easy, so you just want exceptions out of it.’ *(Mr D, May 2005)*

Milk meters were an obvious requirement in meeting this goal and although his OnFarm system could be fitted with milk meters Mr D was not convinced of the reliability of the OnFarm meter product. Purchase of the *ICT-1* system was based on Mr D’s perception that it was internationally proven and reliable with good local service. Another key factor was the ability to proactively manage cows with *ICT-1* during milking with live on screen data. An interactive touch screen on the heat detection platform was eventually installed, but was only used to a limited degree due to networking problems between the screen and main computer.

The new ICT system was installed in a progressive fashion, with the software component installed over a month before the milk meters. Problems occurred with accuracy and reliability of technology components, for example networking issues with the touch screen, inefficiencies in the drafting system, automated teat sprayer problems, and misidentification of cows related to inability of the system to
recognise when a bail is empty. These issues proved a distraction for both dairy farm employees trying to learn to use the new system and for ICT-1 technicians who were required to spend time on problem solving rather than training. While Mr D said that the company was responsive to problems, after 12 months with ICT-1 he expressed his frustration saying he would not reinvest if given the chance again. He went to the extent of detailing his concerns in an email to the Australian and international head offices, after which a group of technicians spent several days on the property. The situation was resolved to an extent where six months later Mr D was comfortable with his investment decision.

Implementation of the training programme was held back by the system faults. Initial instruction was provided at installation and informal guidance was given when technicians were on farm to fix the faults, but it was eight months before the ICT-1 retailer conducted formal on farm training. Both the herd manager (HM-1) and Mr D found the changeover from OnFarm to ICT-1 a challenging period and the latter acknowledged they still had more to learn.

‘We’re going to go through a big learning curve, like we’ve got a high degree of knowledge, but it took us probably a month or 6 weeks to get us back to where we were with the OnFarm program.’ (Mr D, May 2005)

Mr D and HM-2, a herd manager employed later in the case study (see below), commented that they found the ICT-1 software harder to learn and less intuitive in design than OnFarm. They acknowledged that the level of functionality and flexibility was far greater in the new software which possibly accounted for the complexity.

A vital part of training and support during the early learning period was the ability for ICT-1 technicians in their Melbourne office to link into the dairy computer using PCAnywhere™ through the internet. This enabled Mr D or HM-1 to ring technicians for advice and then be shown the process on the computer screen while being talked through it on a mobile phone. HM-1 was most involved with ICT-1 on an operational basis, entering data and reviewing alerts, and he received some training from both the retailer and Mr D. General farm employees were given
little if any training with the system initially because Mr D wanted to wait until it was functioning correctly. Mr D was generally unimpressed by the ability of ICT-1 technicians to provide software support, and found the official manual too general and non-intuitive.

‘They actually don’t have a good operators manual, you know their manual is filled up with some operational stuff and all the things of how to fix it and how to install it, and so the system lacks a concise well laid out operator manual. You know, you want to change the feed ration for the cow this is how you do it.’ (Mr D, November 2005)

In late 2005 Mr D engaged Trainer-1b (see section 4.2) as a consultant to provide general herd management systems advice, including use of ICT-1, and found his practical knowledge base an improvement on that of ICT-1 technicians.

‘They (ICT-1 technicians) have actually lacked operational knowledge, where Trainer-1b has been fantastic like that (Mr D, November 2005)

‘He's (Trainer-1b) done a fair bit of education work with (HM-1) on the computer and taught him how to read all the graphs and stuff because it's quite a powerful system with the knowledge that comes out of it and Trainer-1b understands it, he started to put procedures in place for (HM-1).’ (Mr D, May 2006)

Simplified flow charts of certain ICT-1 processes were designed by a technician, Trainer-1c, and used at Mr D’s farm. Trainer-1c also spent a day on the farm providing guidance and observing milking routines in order to identify reasons for the ongoing problems.

HM-1 was a key link in utilisation of ICT on this farm and spent between 30 to 60 minutes per day entering data, with more time during calving and insemination periods. However his overall computing and analytical skills were limited according to Mr D and external trainers, and he was slow to adopt time saving features such as batch entry of data. HM-1 was also reluctant to delegate data entry
responsibility to other employees leading Mr D to comment that he spent too much time at the computer rather than managing. In mid 2006 a new herd manager (HM-2) was employed and given broader management responsibilities while HM-1 was reassigned but retained some data entry responsibilities. HM-2 also had previous experience with OnFarm from another property and took a greater analytical approach to ICT-1, installing it on his home computer to review data after work.

Examples of the learning process on this farm include the use of new data collected via ICT-1, and adaptations that were made to the system.

Learning to use data
Utilisation of ICT for operational management such as in-shed alerts and entry of breeding and health data was well established before the adoption of ICT-1. The new software allowed the option of continuation of operational management tools, but also provided increased tactical management opportunities as listed below.

- A daily situation report was constructed to automatically print-out at 4.30am to alert staff to cows with low milk yield and high conductivity. Conductivity was used as a trigger for visual examination of cows with possible mastitis infection.
- ICT-1 was used to run a trial on a new reproductive drug where half the cows received the drug treatment and half the cows did not. According to HM-1, it was the flexibility of the new software that facilitated the administration and analysis of such experiments.
- A dry off/cull report was used that was based on the daily milk yield per cow. It was based on a report Mr D had previously used in Excel™, driven by monthly herd test data, where cows not producing milk above a set margin over input costs were flagged for either culling or drying off depending on their health and lactation status. An ICT-1 technician created an ICT-1 report to perform the same function using daily milk yield data and enabling easy identification of relevant cows during milking.
- Late in the case study Mr D learnt from ICT-1 trainers how to include condition scoring as a component of the feeding calculation allowing cows in poor condition to receive a positive base ration correction, and cows in very good condition to receive a negative ration correction.
Mr D and HM-1 built reports through a mix of self learning, ICT-1 technician advice, and Trainer-1b guidance. HM-1 commented that he found Trainer-1b’s advice easier to follow but it is obvious that the retailer was also instrumental in supporting the advancement of ICT utilisation on this farm.

**Adaptation of ICT**

Increasing efficiency in herd management was a key focus for Mr D. An example was the use of the auto drafting system that was originally installed with two way drafting. After noticing that slow auto drafting operation impeded cow flow off the milking area Mr D investigated and found that the gate returned to a pre-set position regardless of the predominant drafting direction. As a result Mr B suggested to the ICT-1 retailer that the drafting software be rewritten to enable the system to recognise predominant cow drafting direction and adjust to it by automatically altering the pre-set position.

### 4.5.3 Critical issues

The key factors driving learning and increased ICT utilisation on the case study farm were the extensive prior ICT experience, the role of HM-1 in ICT-1 use, roles and responsibilities in regard to training, and the impact of Trainer-1b. Due to the farm size and complexity, this case provides an example of dairy ICT learning at an organisational level rather than just an individual level. Also highlighted in this case is the impact of an engaged user pushing the limits of a technology and the resulting adaptation process.

Prior ICT use for farm management provided an advanced starting point on this farm compared to others in the case study. The learning challenges were focussed less on developing general ICT skills and more on converting previous ICT knowledge to operation of the new system, and taking advantage of its more advanced capabilities. Even with prior experience, there were significant implementation costs identified by Mr D. He suggested another AU$30,000 was incurred in costs from time spent on the system, extra mastitis cases, and lost production. While these cost estimates are anecdotal, they do highlight potential
downstream costs post installation which farmers need to consider when making ICT investment decisions.

The greater degree of management complexity in such a large enterprise generates a very different ICT learning environment compared to that of small family farms. On a small farm, one person may be responsible for operational, tactical, and strategic management decisions whereas on Mr D’s property responsibilities were initially split between Mr D as owner, HM-1 as herd manager, and general staff. Mr D exhibited a highly analytical management style, and his classification as an ‘Assimilator’ in a Kolb learning test (Kolb 1984) highlighted a strength in inductive reasoning. The assimilator learning style was identified by Cross et al. (1994) as well aligned with use of ICT systems and this combined with Mr D’s computer literacy made him well suited to use of ICT-1 however he was disconnected from regular use of the system due to his off-farm. Consequently, application of his analytical skill was not maximised.

‘The management system is far from perfect, it would be much better if you were an owner operator working for five or six days a week, that would make a difference because there is nothing like the dedication of an owner operator to get things going properly, so at the end of the day perhaps I’ve been a bit slack and should have put more time in.’ (Mr D, November 2005)

The added levels of management generate both opportunities and threats to ICT learning as they allow for division of roles (data entry, data analysis) but can also lead to inefficiencies or confusion from overlapping responsibilities, and potential data errors. The primary ICT-1 user was HM-1 however his focus was on data entry and use for operational decision making as opposed to more sophisticated tactical or strategic analysis. As herd manager, his 30-60 minutes spent each day using ICT-1 could have been reallocated to another staff member simply through delegation of data entry tasks. When appointed, HM-2 moved to instigate more efficient ICT responsibilities by using ICT-1 for tactical and strategic management tasks while leaving HM-1 to continue data entry. Potential roles within the
management structure on this farm are presented in Table 4.1 below where the herd manager and staff are allocated more specific roles than currently exist.

**Table 4.1: Actual and potential delineation of ICT responsibilities on Mr D’s farm**

<table>
<thead>
<tr>
<th></th>
<th>a) ICT role (Actual)</th>
<th>b) ICT role (Potential)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr D</td>
<td>Oversight, advisory, knowledge creation</td>
<td>Oversight and tactical analysis</td>
</tr>
<tr>
<td>Herd manager</td>
<td>Data entry, use of reports</td>
<td>Interpretation of data, knowledge creation, report creation</td>
</tr>
<tr>
<td>Staff</td>
<td>Little interaction</td>
<td>Data entry, use of reports</td>
</tr>
<tr>
<td>Trainers</td>
<td>Learning support, report creation</td>
<td>Learning support</td>
</tr>
</tbody>
</table>

Physical factors can also impact on ICT use. Location of the main dairy computer was not desirable for encouraging the user to sit down and spend time analysing data. The computer did not need to be as accessible from the cups-on position because the interactive touch screen could be used to view and add simple data during milking. Additionally, installing another copy of the software on Mr D’s home computer and linking it to the main database would have allowed him to allocate time to analysing data while at the computer for other management tasks.

The difficulty for dairy ICT retailers is where to focus their training programmes in order to encourage proficient utilisation. Should they target the management team, the key ICT users, or attempt to introduce all potential users on the farm to the system? If external training focuses on the management team this would infer a responsibility for the management team to in turn train staff. In this case Mr D and HM-1 received most of the formal ICT-1 training with the view that HM-1 would institute a training programme for both existing staff and new staff who may be employed over time. The failure to implement such a programme prevented staff from connecting with the ICT-1 system at any more than just a basic operational level. Employment of Trainer-1b symbolised the ICT training failure up to that point. The features that Trainer-1b offered were based around a mix of ICT-1
knowledge and practical application, or as Mr D described him “a switched on farmer”. A testament to the value of a person such as Trainer-1b, who bridged the worlds of dairy farm management and ICT knowledge, was that the ICT-1 retailer eventually contracted him to train their other clients.

4.5.4 Emergent learning

This case stands apart from the other five farms studied due to its size and complexity. With high staff numbers, an owner somewhat disconnected from day-to-day operation, and emphasis on production efficiency, the farm operates similar to a typical medium sized business. The development of a precision dairy farming system rapidly evolved throughout the case study period and can be likened to a coalescing community of practice (CoP) as described by Wenger (1998). The emerging precision dairy farming system on this case study farm is described below in terms of CoP theory, particularly Mr D’s role as an orchestrator of the CoP and co-developer of the technology.

Communities of practice are dynamic networks of knowledge transfer and shared learning. Such dynamism was exhibited on this farm because over the course of the case study the CoP moved from a potential to an active form; had members join, exit, and change roles; and was in a constant state of renegotiation. Throughout the case study period the community of practice existed in potential, coalescing, and active forms (Wenger 1998).

The ICT-1 installation phase on this farm was similar to the ‘potential’ community of practice stage described by Wenger (1998). The pre-sale process was a key period in this stage where Mr D selected the retailer to purchase the technology from. Here he was selecting the community members with which he wanted to develop a precision dairy farming system. The selection process was based primarily on technology factors, but also Mr D’s knowledge of technological reliability and quality of local agent support.

As the community of practice ‘coalesced’ on this farm, different roles began to emerge for CoP members. Although he possessed the ICT skill, Mr D did not have
enough time to drive advanced ICT use on a day-to-day basis. Conversely, HM-1 had the time but lacked the skills or desire to engage at an advanced level. HM-1 constrained the efficient use of ICT-1 due to his independence from Mr D and other staff. In this coalescing phase Mr D sought to find the best arrangement of community members in order to achieve his ICT-1 goals. When unsatisfied that a member was performing their role adequately Mr D adapted to find another person who would perform the role. For example, when little response was received from the Australian retailer on a technical problem, Mr D emailed the international head office directly with his concerns. Another example is when Mr D, unsatisfied with the ICT-1 use of HM-1 and the training offered by the retailer, contracted Trainer-1b fill the learning support role. In this way Mr D actively created an ICT community of practice, acting to bring in new members and reassign roles of other members in order to achieve the community’s purpose.

In its ‘active’ form the community of practice involved a new herd manager more committed to advanced use of ICT-1. The relationship between Mr D and the retailer had also evolved, through site visits by Trainer-1c, to where the retailer had a greater awareness of the farm-specific issues associated with ICT-1 use. Mr D also developed an awareness of the retailers business, including how to get action on his requests for adaptation and an appreciation of the timelines for such adaptation.

The community of practice ‘lives’ through the links between members, and these links provide an opportunity for reflective practice. With Mr D spending significant time off-farm, there was a greater need for connectivity between him and the herd manager, and between the herd manager and other staff, to encourage reflective practice. As in case study ‘C’, the ability to transfer farm management knowledge between members of the community, and convert this knowledge into an ICT compatible form, is a key factor in the ICT learning experience. Knowledge transfer was negatively impacted by several factors: HM-1’s management independence; a lack of staff involvement in ICT use; and Mr D providing insufficient attention to operational detail.
Throughout the case study Mr D expressed an awareness of ICT learning gaps. This recognition was based partially on previous ICT experience and knowledge of what to expect, but there was also a reflective component. Mr D attempted to address the organisational learning gaps by employing Trainer-1b to implement formal systems for staff to follow. Learning could have been further progressed by including specific staff in ICT use and not waiting for 100 percent operation of the system before beginning training. Mr D saw himself and the farm as co-developers of the technology, and while he expected the retailer to provide adequate training Mr D also acknowledged himself as part of the training process. He saw the farm as an informal beta-test farm, as few such milk meter based systems complete with ACRs, retention bars, kick off detection and auto drafting had been installed in 1000 cow herds. With this in mind Mr D was more accepting of minor problems, as long as he felt they were being addressed by the retailer.

‘It’s new technology for them [the ICT-1 retailer], I think they’ve only put three of these sheds in and these systems have been designed to operate all over the world and they’ve said themselves that usually Australia and New Zealand operates all this equipment differently. So I suppose its one of the downsides, I mean we had the same problem with [previous ICT system], like they couldn’t get the ID system working properly and it turned out to be interference. You go in early days with any technology, any company, and you’ve always got issues to work through.’ (Mr D, November 2005)

Emergent learning from this case for service providers centres on the pre-sale and installation phase of ICT use. Service providers can take divergent views of ICT installation on a large dairy farm: either negatively in terms of the operational complexity and consequent potential for technical and social difficulties; or positively in terms of harnessing opportunities emphasising the various technical and social components as a resource to be managed for mutual benefit. If on-farm resources can be harnessed from the outset, the ICT learning experience can be maximised and the ongoing service provider input minimised. In large dairies operating to maximise marginal returns the consequences of ICT failure, such as
incorrect identification of an antibiotic cow or inefficient data management, are magnified when compared to a smaller farm.

At the pre-sale stage attention should be given to ‘profiling’ the farm operation in respect to ICT use. The profile, formally discussed between buyer and seller and detailed as a short report, would entail: ICT goals, and current human resource roles, responsibilities, and skills. With a relevant farm profile, the buyer and seller can then work together and create a systematic approach to ICT use, explicitly setting expectations around learning, responsibilities, and knowledge transfer.

In conclusion, analysing the use of ICT-1 on Mr D’s farm as a developing and dynamic CoP provides an insight into the emergence of a precision dairy farming system on a large farm. Mr D was an active participant in the CoP development, acting as an orchestrator of the community by choosing its members, seeking people who provide a value and replacing people who were not performing. This active approach, motivated by Mr D’s drive to achieve his precision dairy farming goals, led to a rapid evolution of the CoP. By acknowledging his role as a co-developer of the technology Mr D was less distracted by development issues and more focussed on getting the technology to achieve his goals. Most of all Mr D exhibited awareness that the development of a precision dairy farming system is a dynamic process and that flexibility and adaptability were required to achieve his system goals.

4.6 Mr E – On the threshold of PDF-ICT investment

4.6.1 Case description

Mr E operated a New South Wales dairy farm in a four-way partnership with his wife, father and mother, along with one fulltime worker. The family had a long history on the property which was converted to milk cows in 1930. Goals for the business were centred on growth and diversification, with a 5-year target of 300 cows producing over 8000 litres. By 2007, Mr E aimed to have initiated an education and tourism centre on the farm, focussed around the history of milking.
practices. At the beginning of the case study Mr E was involved in the wider dairy industry through a seat on a dairy industry board, involvement in conferences, and enrolment in farm management courses. Deregulation of the Australian dairy industry in 2000 prompted Mr E to reassess his continued role as a dairy farmer and he made the decision to intensify and reinvest 85 percent of the restructure package\(^1\) back into the business. A key part of intensification involved increasing milking efficiency by replacing the old walkthrough dairy with a rapid exit herringbone.

At the start of the study, 150 Friesian cows were milked at peak on 160 ha (40 ha irrigable), with an additional 40 ha used for dry stock. Dry conditions had led to a dependence on off-farm feed sources, and the proportion of daily cow intake fed via the feedpad had increased 50 percent to almost 100 percent over the past three years. Approximately 3 kg grain/cow/day was fed in the dairy in mid 2005. Year-round calving was used with a recent focus on maximising production from February onwards to exploit higher winter milk prices.

Mr E had a contract with The University of Sydney for veterinary and nutritional advice. Private consultants had been used in the past but at the time of the case study occasional tactical advice was sought from the local Department of Primary Industries. Monthly herd testing was also carried out. In terms of ICT, a herd health software program designed by Mr E’s Vet was used on the farm but more expansive herd management programs were not used. The home computer was also used for financial reporting, email and internet. A hard copy diary was maintained for herd health and health and safety reporting.

\subsection*{4.6.2 Significant events}

The walk-through dairy, built in the 1960s, had been expanded over time from a 2 double-up to an 8 bail system capable of flat-rate feeding. In October 2005 it was replaced with a 12-aside double-up rapid exit with potential for expansion to 16-aside. An NLIS eartag based ICT-3 system was also installed that included milk

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\(^1\) An assistance payout provided to Australian dairy farmers during the industry’s deregulation in 2000.
meters with conductivity, auto-drafting, ACRs, and individual feeding capability. Mr E was the only case study farm with a ICT-3 system, and was the first farm in Australia to install this system. The management software was loaded on a computer located in the new dairy, but was not easily accessible from the milking pit.

Mr E’s goals for ICT-3 centred on implementing individual feeding and achieving efficiency gains. He expected labour efficiency to be enhanced via use of auto-drafting, automatic collection of data, and general streamlining of milking procedures with in-shed alerts. Gains in feed efficiency and the milk-to-grain ratio were also expected through the use of feeding to production. Increased decision-making timeliness was anticipated from use of daily milk data as opposed to monthly herd test data. Stronger tactical management was targeted via use of more comprehensive data for optimising calving pattern, feed budgeting, and estimating milk income.

Implementation of ICT-3 as a management tool during the case study was hampered by operational issues and technical problems. The EID system was not linked to the database for up to three weeks post installation because Mr E had to wait for the NLIS internal chip numbers. Consequently no individual cow data were captured during this period. Problems were also experienced with milk meter accuracy in the first two months of operation. A fault disabled six milk meters for several weeks in late 2006, low vacuum pressure coincided with significant mastitis issues, and a power overload knocked out the auto-drafting system for over six months. These problems, occurring throughout the case study, undermined utilisation of ICT-3 to the extent that individual feeding was not enabled at all in the first 18 months of operation.

From the outset Mr E acknowledged that there would be a time investment required in order to learn the new software, something that had been reinforced by visits to other farms using similar technology.

‘There’s gonna be a lot of learning and a lot of playing around before we fully understand the system.’ (Mr E, September 2005)
Mr E expected significant new learning personally and a steep learning curve for his father and therefore had looked for software with high ease of use. He also viewed ongoing training as a prerequisite and according to Mr E the ICT-3 sales package included up to a week of post-installation training, 24 hour phone support for the life of the software, and software updates.

Prior to installation Mr E was provided with a demonstration version of the ICT-3 software which he used to familiarise himself with the system. At installation Trainer-3 provided a half day on-farm training session, running through the basics of the software and how to enter data. More advanced training on report creation was not undertaken due to the absence of sufficient data, and this training was deferred to a later date. After four months of operation the expected follow-up training had not eventuated however two phone trainings were completed. Further on-farm training was expected before 15 months of use but had not occurred by the completion of the case study.

Mr E did not view paucity of training to be a major issue in his ICT-3 learning and use as he found the software easy to use.

'It’s very simple to enter data and delete data. So that’s fairly simple to do, entering new cows into the system you just follow through the boxes, that’s easy.' (Mr E, February 2007)

He was happy to be talked through issues on the phone, and broadband internet access in the dairy office enabled Trainer-3 to undertake distance training using PCAnywhere™ software. The impact of being the first Australian user of ICT-3 was noticeable as Mr E perceived that Trainer-3 was learning how to use the system as much as he was. Training was the responsibility of the Melbourne head office. The local service agent, who was new to ICT-3 and not proficient in its use, was responsible for support of the milking equipment. The process for addressing problems or learning ICT-3 features was to ring the Melbourne technicians first and if there was no resolution an on-farm visit would be arranged. Travelling distance
and lack of skilled technicians were factors in the limited access to on-farm training as it was difficult for Trainer-3 to get time to visit in person.

Herd health software written by a local veterinarian was previously used to manage health and breeding records and Mr E was confident with its use along with software used for financial management, and email and internet software. Mr E discussed ICT-related ideas with veterinarians during their farm visits and also used them to aid in creation of reports in ICT-3. In general he found the new software very easy to use, especially for entry and analysis. Mr E was the primary ICT user; his father and milker only interacted with ICT-3 on a basic level during milking, for example auto-drafting and using keypads to check cow status while using a whiteboard to note details for Mr E to enter into the database later. The reliance on Mr E was highlighted when he travelled overseas for one month and returned home to find the ICT-3 processor had been accidentally turned off and no milking data had been recorded since he left.

Introduction of ICT-3 streamlined information management on this farm. Data storage and analysis is now centralised in the dairy office, rather than in the house, providing a strong link between information for decision making and actual implementation. Mr E now spends up to 30 minutes after each morning milking entering data and checking reports for cows to be drafted, replacing data input and printing a drafting report, tasks which had previously been completed on the home computer in the evening. Information is quickly accessible before, during, or after milking and he no longer has to walk to the house to check data. In late 2006 Mr E made a further investment in ICT, this time in the form of farm mapping software. The aim was to enable better record keeping with less paper work, particularly in respect to health and safety requirements. The software primarily focussed on land resource aspects of the farm operation not covered by animal-focused ICT-3, but there was no ability to transfer data between the two programs.

Specific examples of Mr E’s use of ICT-3 are outlined below in respect to individual feeding and report creation.
Individual feeding

Although individual cow feeding was listed as one of the primary motivators for investment in ICT-3, this capacity was not enabled during the first 18 months. Instead a flat feeding rate of around 2kg/cow/day was dispensed in the dairy. The desire to change from blanket feeding was driven by experience with augers in the old dairy that were inaccurate and difficult to calibrate and the desire to increase production and profitability by tailoring feed to individual cow production. While Mr E was confident in the accuracy of the new system, and happy with its ease of calibration, drought, herd management practices, and technical problems inhibited him from taking the next step and feeding according to individual milk yields. The technical problems outlined previously resulted in inconsistent data capture from milk meters and eroded Mr E’s confidence with data use. Another reason for continued flat feeding was the marginal benefits of change due to cows receiving relatively small amounts of grain in the dairy (reduced from 3 kg/cow/day in October 2005 to 1 kg/cow/day in February 2007 due to limited grain supply and costs). Almost their entire daily intake was supplied as forage via the feedpad.

The third key factor inhibiting the use of individual feeding was lack of herd management adaptation. Dry cows and young stock were only fitted with EID tags upon returning from the run-off block or agistment, posing a risk of fresh cows being milked before they were listed in the database. Wary that unidentified cows would not receive grain if individual feeding was enabled, Mr E’s management response was to maintain a blanket feeding regime until all cows in the herd had an EID tag recorded on the database. If young stock had been proactively tagged before leaving the farm, or systems were put in place to tag them on their return to the farm, the risk of milking unidentified cows would have been negated.

While new learning has been minimal in the area of individual feeding, Mr E did express an expectation that Trainer-3 would show him how to set up individual feeding once the technology was operating correctly.
Use of daily information

Tactical use of ICT-3 centred on the creation of reports to identify cows falling within certain health and production parameters. Mr E used a mixture of experiential learning and external advice in his learning process, creating two reports in combination with his veterinarian and two reports on his own. For example, in developing a cow dry-off report, Mr E worked with his veterinarian to adapt a format used in the previous herd health software, setting a filter to identify cows over 200 days in calf or with low milk yield.

Using daily conductivity readings is another example of the role of others in the learning process. Mastitis problems were previously identified directly from visual cow appraisal, high SCC cows in herd tests, or by high cell counts in daily factory tests. If mastitis cows could not be found visually during milking then each cow in the herd was tested with a rapid mastitis test. This approach was adapted using ICT-3 through use of high conductivity alerts in the milking pit, or conductivity peaks observed on the dairy computer, to trigger immediate visual inspection during milking. The use of conductivity in mastitis detection involved learning to interpret which trigger values justified further attention, a process aided in the early stages by ICT-3 technicians.

‘We checked a couple of cows that had high conductivity but they’ve been alright, but when the technician installed it he said that we might find cows with really high conductivity, but it doesn’t mean anything, that’s where they normally are, but then you might have some that record a low conductivity and they’ll show signs of mastitis. So we’re still coming to grips with how it’s going to work and what to look for and everything. So that’s a learning challenge.’ (Mr E, November 2005)

4.6.3 Critical issues

Previous use of herd health software and other more general computer software equipped Mr E with the ability and confidence to easily adapt to ICT-3. Other critical factors driving learning and degree of use were ICT-3’s ease of use,
perceived usefulness, access to training and support, and the current farming environment.

When assessing ICT-3, Mr E benchmarked it against the previous herd health software and found it as easy to use. The ease of use was offset by limitations in ICT-3’s overall usefulness for Mr E’s management needs. As an example, there was no capability to graphically represent data, a feature that Mr E prefers when tactically appraising herd performance. Also Mr E wanted to record more details on artificial insemination such as technician name and resulting conception rate but this was not possible in ICT-3. To graph such data Mr E had to write down the key details from ICT-3 and transfer them to another program. Consequently the ability to monitor the impact of different management practices was restricted, and opportunities for efficiency gains were lost because of continued double-entry.

The version of ICT-3 software installed on this farm was a basic version designed to be used in sheep and goat dairies, in addition to cattle. It was therefore highly flexible for use in different farm systems but was not advanced in areas such as batch entry functions or tactical management.

‘From what we were told we would be able to do to what we can actually do didn't match up basically so that, the expectation of what we were told we could expect to be able to do with the software is completely different to what we can do.’ (Mr E, February 2007)

Usefulness of the ICT system was also impacted by cross-platform compatibility issues, for example the inability to upload monthly herd test data into ICT-3, a feature promised in pre-sale discussions. As a result Mr E could not easily compare milk quality factors with milk yields for individual cows. Lack of compatibility between ICT-3 and the herd health software also led to double-handling with continuation of the hardcopy diary required to supply veterinarians with the data to then input into the herd health program. Prior to purchase, Mr E expected to be able to synchronise ICT-3 with herd health software, however this was not the case. In fact no data could be exported from ICT-3. Another factor impacting usefulness was the quality of data stored in the database. Data capture
was disrupted initially by slow input of cow identification data and later by milk meter faults. These combined to reduce Mr E’s confidence in collected data and therefore impacted on his use of milk yields to determine individual feed rations.

The current farm environment was also a major factor in learning and use of the dairy ICT. Drought conditions forced Mr E into a holding pattern with his management, putting on hold plans to expand the herd size. Severe mastitis and consequent loss of premium quality milk payments led to 40 cows being culled, taking the herd size down to 120 cows. The small herd size made use of ICT for individual management less critical as tacit management processes could be effectively used. It also created less incentive for time and money saving features such as batch entries and grouping cows for feeding. A key example is the limited impact of a fault in the auto-draft system that put it out of action for over six months; the small herd size combined with adequate staff numbers meant that cows could be identified and manually drafted effectively. Another example is that low grain feeding rates in the shed didn’t present enough potential benefits to induce Mr E to fast track the implementation of individual feeding.

The purchase of farm mapping software highlighted several features of Mr E and his interaction with ICT. It showed his desire to manage with the aid of ICT tools on a whole farm basis, not just in terms of animal production and health. Also apparent was Mr E’s ability to adapt to use of new ICT without a need for extensive training.

While Mr E has confidence in his ability to use ICT tools, he also makes good use of outsiders in his learning process. However, there was little evidence of a reflective learning process and outsiders were seen as problem solvers as opposed to facilitators of a learning process.

*Mr E:* ‘I did get into a little bit of difficulty when we first put the program in, I deleted a couple of cows, it said they were removed from the herd but they weren’t, so it took me a while to work out how to bring them back again.
*Interviewer:* So did you do that yourself or did they?
Mr E: They did show me, but of course I didn’t take much notice of it, I said I’m not stupid enough to do that. But I managed to work it out.’ (Mr E, February 2007)

The formal training delivered by the service provider did not match initial expectations but no negative impact was felt by Mr E, due to his own ICT skills and the ease of use of the software. When faced with a specific problem, Mr E would contact Trainer-3, but when looking to analyse data for tactical decisions he would consult his veterinarian in particular. Mr E also considered using a friend who he considered to be an ICT specialist to investigate creating new software to pull relevant data from his ICT tools into one interface. Support from the Vet service has been integral in Mr E’s management with regular contact for pregnancy testing, condition scoring, and nutrition advice. Their ICT input aids Mr E to push further up the ‘data-information-knowledge-wisdom’ continuum, in converting information to knowledge.

4.6.4 Emergent learning

The experience of Mr E provided an insight into the use of ICT in a small dairy operation, at the opposite end of the scale from Mr D’s large dairy farm. Herd size at the start of the case study was similar to that of Mr and Mrs C’s farm, but the extent of ICT use was different. This case study farm also illustrated the impact that unforeseen and uncontrollable events can have on achievement of goals for dairy ICT. The subsequent emergent learning discussed in this section involves: the importance of each of the three core competencies identified in Mr and Mrs C’s case, the existence of a threshold above which precision systems provide a benefit over previous management systems, and the opportunity that ICT systems provide for reflexive practice.

The core competencies identified in Mr and Mrs C’s case (skill, enthusiasm, knowledge transfer) can be used as a lens to examine Mr E’s use of ICT-3. Mr E was competent with computer software and had significant prior use and therefore his skill level was sufficient to use ICT-3. He exhibited engagement with ICT in general, an example is his later investment in farm mapping software. As the
primary decision maker he was also well connected to all aspects of farm management therefore knowledge transfer was not an issue. The difference in use between Mr E and Mr and Mrs C is therefore not due to lacking core competency, rather it involves the extent to which ICT was required to augment his current management practice.

During the case study Mr E’s farming operation was severely impacted by drought conditions. Reduced herd size and a new efficient dairy, with no associated reduction in staff numbers, meant that herd management issues were able to be solved without reliance on ICT. Mr E had extensive contact with veterinarians, dairy researchers and consultants, and this combined knowledge also facilitated control over animal health and feeding issues. Mr D, as discussed previously in this chapter, installed milk meter based ICT with the aim of achieving control over production and animal health at an individual cow scale in his large herd. Subsequent improvements came from increased accuracy in identifying low producing cows, cows with potential mastitis, and increased timeliness in decision making around culling and drying off. Mr E’s ICT goals were also centred on achieving control through use of individual feeding and general efficiency gains. However, the system was used for flat feeding throughout the case study period and benefits from ICT came through maximising efficiencies rather than significant system adaptation.

The benefits of using advanced dairy ICT systems as investigated in this study were achieved through improved management control over individual cow variability. Improved control suggests achievement of a positive change in herd management outcomes, when compared to previous management practice. In Mr E’s case the initial goal of increasing management control through use of ICT was impacted by his management response to continuing drought. By delivering close to 100 percent of the herd ration via the feedpad and minimising use of grain Mr E lost the ability to control intake at the individual cow level. This was a logical response to the combination of a lack of pasture on offer for grazing, the relatively high price of grain, and the comparably cost-effective use of a total mixed ration. However, as a consequence it eliminated the potential use of daily milk yield data for a production-based feeding regime.
The potential value of precision dairy farming systems is linked to the relative increased control compared to the current management system. Farm size and complexity impact on a farmer's ability to maintain control. Management of large dairy farms involves controlling greater complexity of human resources, feed inputs, and animal performance/health compared to smaller farms. As a consequence the marginal benefits, such as maintaining individual cow attention and labour savings, of advanced ICT based herd management systems increase with herd size.

Mr E's experience suggests the presence of a threshold below which advanced ICT based herd management systems present little marginal benefit. Herd size is not the only determinant of such a threshold: the farm human resource mix, and the system control exerted under previous management practice are also important. Without drought impeding on-farm feed production, and at his target herd size of 200 cows, Mr E's current management practice may have provided inadequate control thus providing an incentive to utilise ICT-3 more fully. With 120 cows, and reliance on feed delivery via a feed pad, the same management outcomes could have been achieved without an advanced dairy ICT system. An example of the latent technology is the auto-draft system which was inoperable for up to six months with little impact on management efficiency. This case highlights the need to focus on ICT system goals to guide the level of investment in ICT components where marginal benefits will be achieved. In some instances, such as where herd size is small or the farming system is relatively uncomplicated, expensive milk meter technology may be unviable.

Advanced dairy ICT represents a sunk cost due to its high depreciation and lack of a resale market. This emphasises the need for greater consideration of the marginal benefits in the pre-purchase phase.

The development of a precision dairy farming system on Mr E's farm was also stifled by the limited options provided by the ICT-3 system for data analysis. The ability to adapt management through reflective practice is an important feature of double-loop learning (Argyris & Schoen, 1974). ICT can facilitate reflection by
providing opportunities to review the impact of decision making on key management indicators and trends, particularly useful for tactical and strategic management. **ICT-3** was limited in this regard, showing less flexibility than **ICT-1** or **ICT-2**. Mr E was frustrated with the inability to export data or represent data in a form, such as graphs, that he was accustomed to with other herd management packages. This limited his ability to use the data collected for anything other than operational management, representing a missed opportunity for improved control at the tactical and strategic management level.

In comparison to **ICT-1** and **ICT-2**, the system used by Mr E (**ICT-3**) was not widely used in Australia. As a consequence **ICT-3** training support delivered to Mr E was the least comprehensive of the three systems used by farmers in this study. Training was based out of Melbourne, as with the other two retailers, but only one on-farm training session was provided and there was no opportunity for user groups. When problems occurred Mr E had difficulty obtaining support. This raises a question around the degree of support deliverable as face-to-face learning versus distance learning methods. Mr E was comfortable learning over the phone while **Trainer-3** used PCAnywhere™ to demonstrate on Mr E’s computer from Melbourne, but he lacked the support of a local learning network to provide ideas and enthusiasm.

In conclusion, the limited system change between Mr E’s previous herd management and his herd management after installation of **ICT-3** highlighted several emerging issues. While fulfilment of the three core competencies (skill, engagement, and knowledge transfer) are important in a successful precision dairy farming system, the new system must also offer a marginal benefit over the previous farming system. A threshold exists below which the return on investment is minimal, and system goals should be carefully matched to capital investment because dairy ICT investment is primarily a sunk cost. Precision dairy farming systems have evolved in response to a need for improved control over large and complex dairy systems. Their use with smaller herds may centre on minimising farm labour inputs, rather than efficiencies in feeding or management by exception.
4.7 Mr F and Mrs F - The tale of two systems

4.7.1 Case description

Mr and Mrs F operated a family farm in northern Victoria with one fulltime and four part-time staff. In their early forties with three children, Mr F was the fulltime herd manager, with Mrs F responsible for farm accounts and herd record keeping. The additional three staff were family members who, with Mrs F, equated to one full time equivalent. Mr F had lived on the farm his whole life. After Mr F left school, he completed a three year farm apprenticeship. Mrs F was not from a farm originally but had worked for a local herd testing organisation. Goals for the farm included milking 50-100 extra cows by 2007, developing a straight Friesian herd producing 9000-10,000 litres/cow/year, and being debt free in 15 years. The farm was in an expansion phase with increasing herd size and a new dairy was commissioned to accommodate this growth.

Three farms were amalgamated in 2001 to create a 135 ha flood-irrigated milking block, with 80 ha as a runoff. At the time of the initial interview, the farm was run as two blocks with cows calved in one mob but then split into two herds and milked in separate 12- and 10-aside double-up herringbone dairies. Peak herd size was 400 predominantly Holstein-Friesian cows (3 cows/ha) managed in a split calving pattern (70 August-October: 30 March-April). Severe drought in the region, along with restricted irrigation water allocations, drastically impacted on the ability to grow grass on the farm during the study period. The cost of purchased feed slowed the planned herd expansion.

Herd testing was conducted every six weeks and results were loaded via email into an Australian-designed herd management software called MISTRO™. Mrs F had extensive experience with the program through her job at the herd test centre and was responsible for the farm’s MISTRO™ program. She used the program to create reports on pregnancy, calving, performance indexes, birth dates, and pedigree certificates. Herd information was recorded by Mr F in a diary used while milking or when out on the farm. Daily herd-scale milk volume, fat, and protein levels from the milk factory were also used for decision-making.
4.7.2 Significant events

The two herringbone dairies were replaced in June 2006 by a new 50 unit rotary with NLIS eartag based EID, milk meters with conductivity, ACRs, a 4 feed head individual feeding system, 2-way auto drafting, and auto teat spray. The herd management software was ICT-1, with the computer located in a dedicated office in the new dairy. Goals for the ICT-1 system included increasing milking ease to enable a one-person shed and enabling feeding to production for greater feed efficiency. Collecting more information on their cows to support decision-making was viewed as a bonus.

Operation of the new shed and ICT-1 components started relatively smoothly and even with twice the number of cows Mr F halved his milking time and ran a one person milking routine. However EID inaccuracy due to a problem with the reader panels led to four or five misread cows each milking session on average and impacted on the utilisation of ICT-1 for almost 12 months. Mr and Mrs F considered the accuracy level unacceptable and it reduced their confidence in the data collected. The inaccuracies had implications for cow feeding, herd testing, and use of in-shed alerts. Misidentified cows would not receive their grain allocation but would be allocated extra feed at the next milking, which would result in a large feed fluctuation for high ration cows. At herd testing time, misreads impacted on the quality of data collected, and the errors also suppressed use of ICT-1 for cow health alerts. Mr F made slight adaptations to his routine to account for the problem, for example when he went to auto-draft a cow during milking but saw she was misread he would place a draft code on the cow in the adjoining bail (the position assigned by the computer system). He was able to identify misread cows through his knowledge of the herd, or by correlating the number displayed with the cow’s freeze brand.

Prior to ICT-1 installation, Mr and Mrs F attended a training day run locally by the retailer where they were introduced to the software and its capabilities. They also received a demonstration version of the ICT-1 software to aid familiarisation but didn’t use it. Mr F was initially unsure what the training program would entail, commenting that it was not a major selling point for the system when compared to
other factors such as price and technical support. They expected to spend only a little more time in front of the computer.

Some brief tips were provided at installation but the primary on-farm training was delivered two months after installation and included approximately four hours tuition by Trainer-1a in the areas of data entry and report creation. Mr F thought the early training was adequate and he expected to continue learning through his own interaction with ICT-1. While he expected to use ICT-1 technicians for learning support at a later date, Mr F anticipated this would be via telephone rather than specific face to face visits. This proved to be the case with no additional formal training conducted through to 15 months after installation. Instead, when he had a query, Mr F might first consult the user manual or call the local dealer for advice. The local dealer would pass the query to Melbourne head office technicians if he couldn’t answer it himself. In general Mr F was satisfied with the amount of training provided as he felt he had built enough of a knowledge base in order to use ICT-1 effectively. While he had used the manual to solve some minor queries he found it generally hard to use. An additional training tool for the retailer was publication of an occasional ICT-1 themed email newsletter with learning tips and worked examples of use. Mr F prints the newsletter and reads through it, although he said that as yet he had not used any of the suggestions.

Mr F developed his skills with ICT-1 to a point where he could adjust individual feed rations, as discussed later in this chapter, and review cow production reports. After each milking he would quickly review two main reports:
1. 'Cows milked last milking' (included: cow number, days in milk, milk yield)
2. 'Milking report' (included: cow number, milk yield, milking date, calving date, 24 hr total, feed consumed, group number, average daily milk, sire, lactation total milk)

He enters the basic information required to enable milking and individual feeding decisions such as calving data and dry off date. The database is not used to record further details such as health problems or treated cows. A report was also created for herd test day for sending to the herd improvement centre and listed jar number, stall number, cow number, milk yield and milking time for each cow.
An overlap developed in herd management software use on this farm, with both ICT-1 and MISTRO™ being used. After two months of use, Mrs F was not certain how much they would utilise ICT-1 in tactical management currently performed by MISTRO.

‘I’m gonna run two systems because I think you still need to run MISTRO for your herd testing anyway, so I haven’t decided whether to use it (ICT-1) to its potential, or just use it, let it milk, whether to put it (cow data) all in.’
(Mrs F, August 2006)

While ICT-1 is focussed on control of components on the milking platform, and the collation of data collected by sensors, it also performs similar general herd management functions to MISTRO™ and could conceivably be used as the sole herd management software. The MISTRO™ software was primarily designed to manage herd test results and breeding records and it is synchronised with many Victorian herd test centres. Through her previous work for a herd test centre, Mrs F developed skills in the use of MISTRO™ and this familiarity was one of the reasons behind its continued use. Also important was the physical location of the software, with ICT-1 loaded on the dairy office computer and MISTRO™ on the home computer which is more accessible for Mrs F and allowed her to be near the children. Lack of compatibility between the two programs was also a problem.

The story of ICT-1 learning is illustrated below in respect to individual feeding and use of conductivity measurements.

Use of individual feeding
The old herringbone dairies were capable of delivering a flat grain ration and therefore Mr F could only make herd scale adjustments, for example feeding more in autumn and winter, leading to inefficiencies in feed use and a portion of the herd being over or underfed.
‘(We) couldn’t do it before (individual feeding), not in the herringbone, it was push and shove and everybody got the same, unless you were bigger and ate more.’ (Mr F, August 2006)

Individual feeding based on seven day average milk yield was enabled in the new rotary in October 2006, after waiting for an on-farm visit from Trainer-1a and resolution of the EID problems discussed previously. Trainer-1a helped to set up the feed tables and the nutrition consultant aided in determining the feeding rate and conducted a six weekly herd condition score and ration reassessment.

Use of conductivity measurements

Mr F adapted his mastitis detection to include conductivity measurements. Previously clots found in the filter or high SCC from the daily milk company vat test alerted Mr F to potential mastitis in the herd. Herd test results were used to a lesser extent due to their relatively infrequent timescale. Mr F began to use conductivity alerts as a trigger to visually assess cows during milking but found mastitis in less than five percent of alerts and tended to ignore them. The local technician adjusted the alert threshold to be less sensitive and now Mr F has enough confidence in the readings that he considers an alert to be an important mastitis identification tool. If the factory SCC reading rises he will first check on the computer for cows with conductivity spikes. Low mastitis incidence and confidence in the use of conductivity as a backup to factory SCC readings led Mr and Mrs F to decide to suspend herd testing.

4.7.3 Critical issues

This case study illustrates that, for a farmer to shift from known software to a new system performing similar tasks, the incentive to change must outweigh the costs of change. In this case, the costs of change were the time required to learn the new software, perceived potential limitations of the new software, and the impacts of using the software on Mrs F in caring for the children. The low level of integration of ICT-1 into the farm management system should also be viewed in terms of the original goals for the technology (based on attaining individual feeding capability) and the impact of drought on farm operations. The drought in particular
was the cause of major adaptation in farm management practice. Mr F had to dramatically increase purchased fodder, and could not grow pasture on much of his property due to lack of irrigation water.

Distinct ICT roles existed on the farm before _ICT-1_ with Mrs F the primary computer user, entering data and creating reports. Mr F became responsible for set-up and maintenance of _ICT-1_ in the dairy office because he spent most time there and Mrs F found it difficult to juggle child care with time at the dairy. This represented a slight shift in ICT roles, although Mrs F expressed a desire to investigate the potential of _ICT-1_ further and take a more active role in its use when some of the children started school in 2008. Mr F uses _ICT-1_ at a level that allows him to achieve his system goals of individual feeding and milking with one person. Both agree that Mrs F with her ICT skills is the key to expanded use of the technology but currently it ranks low on her priority list.

Simultaneously operating two software programs that perform similar tasks inevitably results in lost opportunities for enhanced efficiency. Despite its comprehensive herd management functions _ICT-1_’s role was limited to that of milking and individual feeding. MISTRO™ was maintained as the key herd management software due to familiarity, location of software, and integration into the herd improvement system. When two software programs perform similar tasks the drivers for change can be less compelling for users. If _ICT-1_ was installed on the home computer, and synchronised to the main database in the dairy office via a network cable or wireless connection, this would allow Mrs F to learn and experiment with the software.

The different expectations of acceptable EID accuracy between end user and retailer were exhibited on this farm. On average four to five cows were misread per milking of 400 cows representing 99 percent accuracy. This met the retailers stated operating specifications, but was considered unacceptable by Mr and Mrs F. By the end of the case study the system was operating at an average of 99.75 percent accuracy, or one misread per milking, a level of accuracy that Mr and Mrs F were comfortable with. The different perceptions of acceptable accuracy between user and retailer can be a problem that stems from pre-sale, where
salespeople either overstate the accuracy of their products or fail to clearly notify clients of potential inaccuracy and its implications.

Impacts of incorrect identification on herd management systems depend on the intended use of the data. If the ICT system is relied upon for management of key herd health issues, such as identifying and preventing antibiotic-treated milk from entering the vat, then misread cows can have major implications. Passage of antibiotic-treated milk to a milk tanker can lead to heavy fines for the farmer. On this farm, where the ICT system is only used for more basic functions, EID inaccuracy impacted on ease of herd testing and led to Mr F making adaptations to his auto-drafting routine. Additionally, with the high grain feeding rate of up to 14 kg/cow/day, acidosis could occur from cows being misfed. When users are comfortable with system accuracy it can influence their decision to invest time in learning to expand ICT use and they gain confidence to rely on the technology. An example of the impact of increased confidence on this farm was the decision to stop herd testing and rely on conductivity data to manage SCC spikes.

During the case study period, Mr F was the primary user of ICT-1 and therefore he was involved most in learning its functions. Mrs F attended the early training day but as yet had little opportunity to apply the learning and further her knowledge. A key part of Mr F’s learning was tapping into the expertise of others including the local agent, Trainer-1a, and the nutrition consultant. While he tried to solve problems himself through use of his own knowledge and the user manual, Mr F appeared to be less of a reflective learner and more willing to approach experts for answers. The training program delivered by the ICT-1 retailer enabled Mr F to use the technology to fulfil his original goals, but it stimulated little advanced use. The retailer could increase the use of the email newsletter as a learning tool or provide a forum to highlight the ways in which other farmers are using the technology and the specific benefits they achieve.

While Mr F exhibited a very balanced learning style in a Kolb learning styles test, Mrs F was a strong ‘converger’ with a focus on active experimentation who had confidence in her self-learning ability. She agreed that this reflected her ‘go-ahead’ attitude when it came to using new technologies, preferring to try it out and learn
from mistakes. This style fits well with the general training method of the ICT-1 retailer, where the focus is on building a base knowledge in the user and then providing support when questions arise. If Mrs F recognised farm-specific benefits she would be willing to invest time into use of ICT-1.

4.7.4 Emergent learning

Key emergent learning from Mr and Mrs F’s experience surrounds the concept of knowledge transfer, existence of competency traps, and retailer responsibilities in a developing precision dairy farming system. At first glance ICT utilisation appears to fall short of that exhibited on other case study farms. Mr F primarily used ICT-1 in a functional form to achieve individual feeding, rather than using the data collected for more tactical management. In respect to his goals however, Mr F accomplished his original intentions for the ICT investment. The emergent learning from this case surrounds reasons why Mr and Mrs F did not extend their use of the available ICT-1 functions.

Applying the core ICT competencies of skill, engagement, and knowledge transfer to Mr and Mrs F provides some insight into the ICT adaptation process on this farm. In terms of computer and software skills, Mrs F had experience in herd management software use and felt highly comfortable in its use, whereas Mr F had less experience with computers but learnt ICT-1 competency. Engagement with ICT-1 use was lower in Mr and Mrs F’s case than in other farms studied and some of the reasons for this are discussed below. Knowledge transfer can be broken into two factors: transfer of knowledge between the management team; and transfer of knowledge across the human-computer interface. In respect to the former factor, knowledge transfer between Mr and Mrs F was strong but possibly not as integrated as in Mr and Mrs C’s case. For example, Mr F kept a hardcopy diary which Mrs F needed to access for key mating and health data. Transfer of farm management knowledge into ICT-1 was primarily restricted by continued use of the existing herd management software, a key reason limiting greater incorporation of ICT-1 into farm management practice.
Continued use of existing software, and ‘doubling up’ with ICT-1 use, represents a lost opportunity for management efficiency gains. Mr and Mrs F faced a ‘competency trap’, as identified by Levitt and March (1988), where the difference in potential benefit from a new system was not sufficient to induce them to take on the risk and learning challenge associated with change. The existing software fulfilled most of Mr and Mrs F’s requirements, and it was more integrated with external data transfer structures such as herd test results. Additional factors counting against organisational change on this farm were the constraints felt by Mrs F due to taking care of a young family and difficulties in transferring data between the two software systems. Avoiding the competency trap, and engaging with the learning challenge, requires users to have a clear knowledge of the benefits of new ICT systems as well as the processes necessary to achieve the benefits. Another crucial factor is facilitation of knowledge transfer via greater integration with both existing software systems and existing industry data management structures.

The service provider has an integral role to play in the avoidance of competency traps. Firstly it is important that ICT functionality is matched to the market into which it is sold, particularly in terms of the knowledge transfer factors listed above. Learning support is equally important in helping a user bridge the learning gap. ICT retailers observed in this study generally focussed on getting a system technically operational and supporting the buyer to a level of competency. After this stage they acted as ‘firefighters’, responding when called upon by the buyer to help with problem-solving. The experience of Mrs F provides an example of this, where a long-standing problem with ICT-1 was addressed after she discussed the problem in front of a salesperson and potential clients. Service providers must seek to facilitate a higher level of ICT utilisation than simply competent use as the best advertisement for their products is the achievement of a distinct return on investment by their clients.

Development of a precision dairying system is highly dependant upon engagement of the farm management team. While service providers can not force unwilling users to undertake continued engagement, they are in a position to develop structures that provide the learning opportunities to foster engagement. Currently
ICT trainers are responsible for large geographical areas and struggle to provide more than minimal training to clients such as Mr and Mrs F. Fostering greater engagement requires trainers to spend more time with the user on their farm discussing site-specific management practice and matching it to ICT capabilities. Long term engagement can be supported with facilitation of strong networks bringing multiple users, credible facilitators, and service providers together with a goal of maximised herd management control through use of ICT.

In conclusion, Mr and Mrs F created a precision dairying system which matched their original goals but had significant unexplored potential. Constrained knowledge transfer between Mr and Mrs F, and particularly between the different software systems, was a key factor in the unexplored potential. Insufficient incentive to adapt to the new software led to a competency trap and continued use of existing software. The final theme emerging from this case study surrounded the responsibilities of retailers in expanding the use of precision dairy systems. They currently focus on building basic competency and providing an on-going troubleshooting role, but they could potentially take greater responsibility for creation of learning networks around their clients to promote engagement and develop human capital in precision dairy farming.

4.8 Conclusions

The experience of using PDF-ICT based herd management systems on the case study farms discussed in this chapter provides important insights into issues surrounding the development of precision dairy farming systems. Key emergent learning across the six farms includes: the role of reflective learning; the existence of core competencies for PDF-ICT use; the potential for competency traps to block efficiency gains; and the concept of developing networks via a community of practice around precision dairy farming. By focussing on the first 18 months of PDF-ICT use on farm, the true start up costs associated with the technology were illustrated, and as a consequence the importance of a discussion of expectations at the pre-sale stage is highlighted.
Reflective practice is an important feature of the PDF-ICT learning process. Retailers currently aim to provide core knowledge and then rely on users to engage in self learning to further explore PDF-ICT capabilities. To facilitate self learning through training programmes, and via software design itself, service providers need to encourage farmers to think about how their knowledge management practices can link into a PDF-ICT based herd management system. Creating networks for users to discuss PDF-ICT use, such as with other users, assists farmers to challenge their pre-existing norms concerning the role of PDF-ICT in their management practice. Reflecting on pre-existing norms is a feature of double-loop learners and in the context of precision dairy farming systems the ability to continually reassess perspectives on best farm management practice can provide farmers with opportunities to improve control, risk management, and timeliness through use of PDF-ICT.

The appearance of future precision dairy farming systems will be significantly impacted by the role that retailers take with respect to creation of learning network. From the perspective of the case study farmers, PDF-ICT retailers are currently struggling with the transition from providers of technical milking hardware to providers of an ICT based product with significant associated post-installation learning. Retailers currently provide ‘competency level’ training, in other words they provide enough training for users to achieve competent use of the technology. In addition they act as ‘firefighters’, solving problems that occur with the technology or responding to requests for PDF-ICT support. In Chapter 5 the role of retailers in a precision dairy farming network is discussed.

PDF-ICT based systems rely on data, an explicit knowledge component. In contrast, farmers often operate using tacit knowledge potentially causing a disconnection between farm management practice and PDF-ICT. Poor integration of PDF-ICT into farm management decision making can result. Disconnects can also occur when two people with tacit knowledge on a specific topic attempt to share their knowledge, such as farmers and PDF-ICT technicians. An inability to convert tacit to explicit knowledge, termed externalisation, leads to frustration on both sides, with the farmer perceiving the technician as technical rather than practical, and the technician perceiving the farmer as disinterested or incompetent.
In this situation both parties can work on being more explicit or they could engage a person to translate between the two knowledge domains for example a current or former dairy farmer experienced in the practical application of PDF-ICT on their farm. Individuals who bridge the knowledge domains can prove effective not only because they can translate between farming practice and PDF-ICT knowledge, but because they also have a high degree of credibility with farmers.

Successful integration of PDF-ICT into management practice requires achievement in three core competencies: ICT skills; engagement; and knowledge transfer. Users require at least a level of ICT competency in order to be reactive to new opportunities for applying PDF-ICT in their decision making. Secondly, along with a skill base it is important that users actively engage with the system. The importance of engagement is highlighted by Jago and Calder (2007) who identify a farmers’ own paradigm as the greatest determining factor for achieving a return on advanced PDF-ICT based herd management systems. They suggest significant reflection is needed for adapting management to incorporate the technology. Engagement through a paradigm shift also involves engendering staff ‘buy-in’ to the new system. The final core competency surrounds knowledge transfer, the ability for knowledge to flow between members of the farm management team, and flow between the management team and the PDF-ICT system.

Improved systems or methods will only be adopted to replace an existing system if the potential benefits of the new system outweigh the risk associated with change in addition to the learning required. For example, ICT users can prefer to continue using an outdated interface such as DOS rather than learn to use a new Windows™ based system due to the learning involved (Leeuwis 1993). Thus a ‘competency trap’ occurs where new PDF-ICT systems are not fully utilised due to farmers retaining familiar farm management practices. Incomplete implementation can also occur where a new PDF-ICT system does not match some key feature of an existing PDF-ICT system. Overcoming competency traps begins in the software design phase where designers need to ensure knowledge transfer between their product and other relevant systems, in addition to linking their product into existing industry-level knowledge transfer systems.
In Chapter 2, Cowan (2000) was quoted as identifying several issues related to the degree of precision agriculture adoption, one of which was the significant start up costs involved. Cowan was specifically referring to the costs of ‘material’ components and while this holds true for the farms in this study, with investments over AU$100,000, their experience also highlights the additional costs associated with the implementation phase. These ‘true costs’ of the technology include: the opportunity cost of time spent learning; lost production or inefficiencies during management adaptation; and more direct costs associated with technology faults. While Pedersen et al. (2001) suggest that high equipment cost was the greatest disincentive to adoption of precision agriculture, the greatest obstacle to integration of precision technologies into farm management practice may be the indirect costs of implementation. This is supported by Jago and Calder (2007) who identify the time required to learn the software capability and the potential uses for the data generated as significant costs of advanced PDF-ICT implementation.

Among the other issues identified by Cowan (2000) was the increased need for precision agriculture specialists who were highly skilled in ‘computers, technology, and data management’. Observations of the six case study farmers support Cowan’s statement but also indicate that such a specialist needs a knowledge base in the relevant agricultural system, as discussed above in respect to individuals who bridge the knowledge domains. A final comment by Cowan (2000) relevant to the findings of this case study was the principal role of private companies in precision technology development. This statement holds true for the PDF-ICT systems that currently form the basis of precision dairy farming. The Australian market for advanced herd management systems is dominated by large international dairy equipment retailers. The international origin and proprietary nature of systems can lead to difficulties with data transfer, integrated use of competitor’s components, and latent functionality.

A key method of addressing the potential implementation costs of PDF-ICT is the use of a pre-sale ‘negotiation of expectation’ process. The process involves the buyer and seller explicitly discussing the specific PDF-ICT goals and expectations for technology performance, and establishment of a ‘learning contract’. Learning contracts approach learning as a ‘two-way street’, recognising the responsibility of
the seller to provide a certain level of training but also outlining the expected engagement in learning required from the buyer in order to meet PDF-ICT goals. The purpose of the negotiation process is to establish transparency around the expectation of both the buyer and seller. By addressing potential problem areas, and setting specific performance indicators for these areas, both parties are able to establish a point of reference against which they can track progress.

Combining PDF-ICT learning stories from the case study farms illustrates the importance of the network of people with whom farmers interact as they adapt to the information intensive nature of precision dairy farming systems. In this chapter this interaction has been likened to a coalescing community of practice. Wenger’s community of practice theory provides a framework to explain the formal and informal linkages between farmers, technicians, consultants, and respected peers. The concept is further developed in Chapter 5, along with recommendations for encouraging development of linkages between community members.

Finally, the case study findings are used to address the original research questions from Chapter 3:

1. **How do farmers adapt their management practices to incorporate PDF-ICT systems?**

   On farm management adaptation is highly dependant on farmer goals for PDF-ICT and the particular characteristics of individual farming enterprises. Successful management adaptation depends on three core competencies: ICT skills, farmer engagement with the technology, and knowledge transfer systems.

2. **What learning support networks exist around PDF-ICT systems?**

   Currently there are learning networks which exist around Australian precision dairy farmers, consisting of both formal and informal linkages. Formal linkages exist with retailers, while more informal linkages involve other farmers or consultants. Retailers have attempted to strengthen the learning network through establishment of user groups and newsletters, but these occur sporadically and have currently been of limited success.
3. What interventions are required for future precision dairy systems?

Successful development of innovative precision dairy systems hinges on the ability of farmers to adapt the concept to fit their particular goals and management approach. Additionally, the learning conditions for farmers need to facilitate transition through the early learning phase to advanced use. The six case studies highlighted a requirement for intervention, by PDF-ICT retailers and dairy industry organisations, in order to create ongoing and reflective learning conditions. This idea is explored in more detail in Chapter 5.
5. Developing precision dairy farming systems: Effective networks within a community of practice

5.1 Introduction

A wide range of PDF-ICT use and management adaptation was observed in the six case study farms. However, within this range several recurring themes occurred, including: co-development of knowledge; the importance of learning networks; and disconnections in the support network around precision dairy farmers.

The case study results highlighted the varied roles of actors involved with implementing advanced PDF-ICT based herd management systems on dairy farms. The significance of each actor’s role changes throughout PDF-ICT implementation, as do the links between different actors. In Chapter 4 these changing roles and linkages were likened to the formation of a community of practice, built around the concept of precision dairy farming development. In this chapter the concept of an emerging precision dairy community of practice is expanded. Viewing the case study findings through the lens of Lave and Wenger’s (1991) communities of practice (CoP) concept facilitates exploration of key actors and linkages, to identify aspects that are currently both developed and undeveloped. The outcome of this exploration is used to assess the opportunity for private and public organisations to intervene in a precision dairy farming community of practice.
The theory underpinning communities of practice was outlined in Chapter 3. In this chapter, the community of practice concept is used to examine the key features of a developing precision dairying system at the farm level, along with development of precision dairying at an industry level. The analysis is based on a cross case analysis of the farm business case studies, in addition to findings of the earlier scoping study. Pseudonyms used in this chapter relate directly to those used in Chapter 4. The aim of this analysis is to examine key features of the networks within which precision dairy systems develop, and thereby provide an explanation of strengths and weaknesses.

5.2 Defining a precision dairying community of practice

Defining the community is important for this analysis because it helps to set a boundary around the discussion. According to Wenger (1998) the three key defining features of a CoP are: what it is about (domain); how it functions (community); and what capability is has produced (practice). A PDF-CoP is defined below in respect to the features observed on case study farms.

5.2.1 Domain: What is the PDF-CoP about?

The PDF-CoP is based around integration of a precision farming concept in dairy farm management practice. The precision farming concept is about managing risk and by investing in precision technologies farmers aim to achieve a greater control over variability and risk. As observed in the case study farms, learning to adapt to the new technology and techniques of precision dairying is not something that farmers achieve alone. There are other people involved, both on farm and off farm, and in this chapter those people are included as members of a precision dairy farming community of practice.

Wenger (1998) stated that specific CoP goals are constantly renegotiated by members and this held true for the case study farmers. For example Mr and Mrs C invested in a PDF-ICT system with simple goals focussed on individual feeding driven by daily milk yield measurement. As they became confident with the system they looked to expand its application in farm management, splitting the herd into
virtual management units and adding new hardware such as the somatic cell sensor. This change in use was renegotiated between Mr and Mrs C and the retailer.

Membership of a CoP is transitory with people joining and leaving the CoP depending on mutual needs (Wenger 1998). Mr D’s experience is a prime example of this. Trainer-1b became involved to specifically address Mr D’s needs, which revealed a learning gap in the community. When Trainer1-b had developed systems for Mr D and his staff he then disengaged from active participation in the CoP.

5.2.2 Community: How does the PDF-CoP function?

Engagement between members enables the collective pursuit of the PDF-CoP goal in the form of community (Wenger 1998). At the core of this CoP are foundation members, without whom the CoP would not coalesce. The link between members can be both formal and informal. In the case study farms, the relationship between farmer and retailer was a formal one, based on a service contract for provision of technology and learning support. More informal learning links existed between farmers and respected peers, or farm workers. For example Mr C looked to a friend who had software knowledge to solve a perceived deficiency in the system he was using:

“I've actually got a mate of my partners' that is a programmer, so he ghosted the Hard Drive on the weekend and took it with him, and he's actually going to see if he can extract information out of it” (Mr C – November 2006)

In the PDF-CoP observed in this study, informal links provided a means for farmers to ‘fill in the gaps’ in the community that surrounded them.

A CoP can exist at various levels and in this chapter the PDF-CoP is predominantly described in terms of a community functioning around an individual farmer. Near the end of the chapter, however, an industry-level CoP is discussed where the need for linkages between farmers, between retailers, and with other industry organisations, is examined.
5.2.3 Practice: What capability is produced by the PDF-CoP?

In a CoP, members engage in a mutual learning process, exchanging their knowledge about precision dairy farming practice (Wenger 1998). Through this mutual learning the core knowledge held within a CoP is reflected upon and expanded. Along with a development in technical knowledge of individuals, the linkages between members are strengthened (Wenger 1998).

The capability produced within the PDF-CoP observed in these case studies involved the previous two features of domain and community. More specifically, farmers, retailers, trainers and other CoP members interacted to enhance the farmer’s capability to control specific variable resources within the farm business. In the PDF-CoP however, capability-building was hampered by knowledge transfer between members, and a lack of focus on fostering reflective learning practice. These factors are discussed in more depth later in this chapter.

The PDF-CoP represented a missed opportunity for development of a resilient community knowledge base with an adaptive learning capability amongst its members. Training and knowledge transfer was highly dependant on the relationship between retailer and farmer, and the combined knowledge of farmers was not fully harnessed. For example the knowledge of Mr D could not be sourced by Mr E because there was no direct link between them, and they used products from different retailers. If knowledge is transferred throughout the PDF-CoP not only can farmers learn from each other, knowledge is also less likely to be lost if a farmer, technician, or trainer leaves the system.

The need to foster adaptive learning capability in the PDF-CoP was also highlighted by the different stages of learning observed in the case studies and through the scoping study. Goals of PDF-ICT users changed over time. For example, as farmers became confident with the system, they invested in technology to collect more data, or used their current data in a more sophisticated way. The community ceased to hold meaning for some experienced farmer members. This was due to the PDF-CoP being highly focussed around early
learning, rather than providing meaningful ongoing networks for farmers who had used the systems for two or more seasons. ‘Experienced’ users of PDF-ICT systems interviewed during the scoping study stated that an ongoing community was limited and they were essentially on their own after the early learning phase. The ongoing building of precision dairy capability via an industry community of practice is discussed later in this chapter.

5.3 Community members

The precision dairying community observed in this study consisted of a variety of members both on- and off-farm. A generalised description of the role of each member in the community of practice is provided below. Some actors are termed foundation members due to their integral role in the formation and development of the community. In this section the primary linkages each member has with others in the community are outlined, as depicted in Figure 5.1. The purpose of the analysis is to set a platform from which to critique the present PDF-CoP composition and identify the strengths and weaknesses of both the community members and the linkages between them. In section 5.5 a critical analysis of linkages between key community members is provided.

5.3.1 Relationships in the precision dairying community of practice

The PDF-CoP members discussed in this section, and the links between them, are illustrated in Figure 5.1 as a generalised community of practice. The CoP shown is based around an individual primary ICT user for simplicity; although in reality the community spans multiple users. A multiple user model is discussed in section 5.7. The PDF-CoP consists of core and peripheral learning relationships, where core relationships involve interaction between foundation members and/or involve knowledge transfer that is significant for the development of community-wide knowledge. Peripheral relationships involve members who are more transient or have minor roles in the community, as observed in this study.
5.3.2 Primary ICT user (Foundation member)

Each case study farm had a primary ICT user, defined as the person with the most interaction with the computer software and data. While this was usually the farm owner or operational manager, a farm wife, worker, or consultant could also fill this role. Mrs C was an example of someone other than the farm manager filling the role of primary ICT user. Conversely, in Mr and Mrs F’s case, Mrs F’s skill set fitted the role of primary user best but she could not commit time to ICT learning and use due to the commitment of raising young children. Hence in this case Mr F filled the role.

The primary ICT user is at the centre of the PDF-CoP because it is through them that the data collected are first transformed into knowledge and subsequently integrated into farm management practice. They are one of the CoP’s foundation members because without on-farm application of such knowledge a precision dairy system would not exist. The variety and strength of linkages between primary ICT users and other CoP members depends both on their engagement with precision dairying practices and the inspiration they take from other ‘foundation’ members.
Farmers in the case study took different approaches to adaptation and integration of ICT into their management practice. Because they were at the hub of emerging communities, they had direct linkages with most other community members. However, the strength of these links was primarily determined by the participants themselves. Some took a passive approach to developing CoP linkages (for example, Mr A) whereas others (such as Mr D) were more active in seeking out community members to perform certain roles. The case of Mr B also showed the impact that poorly developed linkages can have on a precision dairy CoP. These examples are expanded below.

As described in Chapter 4, Mr D ran a large and complex dairy farm where he and his staff initially struggled with successful integration of the dairy ICT system due to both technological challenges and on-farm issues around staff responsibilities. Mr D exhibited an active approach to creating links with other actors, thereby proactively creating a community around him. When he was not satisfied with the response of the local and national retailer representatives toward a technical issue, Mr D emailed the global office to initiate a solution. And when unsatisfied with the performance of his herd manager in respect to ICT use, Mr D first engaged a private consultant (Trainer-1b) to undertake training and create systems. Eventually he replaced the herd manager with another manager who had a positive attitude toward use of ICT and implementation of precision dairy practices. In this way Mr D acted as an orchestrator, assessing the features he required in a precision dairy CoP and actively seeking out people who could assist in obtaining those features.

Mr A adopted a more passive approach to network creation. Two of the most important linkages in his CoP came in the form of a new enthusiastic staff member, and Trainer-1b who he interacted with at a retailer-organised user group. Mr A visited Trainer-1b while canvassing systems in the pre-purchase phase, but did not actively seek him out for learning support as Mr D did. Even with a more passive approach Mr A was placed within a community of practice, but this was fostered by the retailer as part of its ICT support role.
In Mr B’s case, creation of an effective network was in part suppressed by his independent management style and ineffective relationships with retailer representatives. While both sides could argue about the reasons behind this disconnection, the end result was significant unfulfilled potential. As an example, where Mr D engaged a consultant to create systems that enabled greater use of the ICT, Mr B engaged a consultant to list technical deficiencies of the system in order to seek reparation from the retailer. Actively seeking a trainer, either from the retailer or privately, to upskill Mr B’s mother or another senior staff member could have led to significantly improved use of ICT and achievement of the original goals.

These three examples highlight positive, passive, and negative approaches to creation of CoP linkages by farmers. While a negative perspective can lead to stifled development of a community around the farmer, a farmer with a proactive approach acts as an orchestrator of the community effectively fostering linkages with external actors as they see fit. Where a farmer takes a more passive approach, fostering of the CoP is reliant on the retailer, resulting in either a higher demand on the retailer or development of a less effective precision dairy system.

5.3.3 Retailers (Foundation member)

Retailers are important members of the CoP, providing guidance as salespeople, technical and problem solving skills at installation, and learning support post-installation. They are foundation members of the CoP due to their role in supplying material technology and providing training support, without which the CoP could not move beyond the incipient stage.

Retailers have the strongest link to the primary ICT user, a link that is more formalised than those between other CoP members due to their responsibilities under the terms of the sale contract. For example the sale contract may specify technology performance criteria and the specific amount of learning support to be provided. Due to these contractual obligations retailers are less transitory members of the CoP, and provide significant support during ICT implementation.
Internal linkages also exist within the retailer’s business structure. Large companies involved in the case studies had local agents, national head offices, and global offices. While most product development is undertaken at the global level, on-farm installation and initial support is provided by the local agent and therefore internal links need to be well developed to enable knowledge flows across levels. For example, specific knowledge of ICT use is often centred at the global or national level, and needs to flow to the local level in order for the agent to be able to support the user. Equally, experience of specific on-farm implementation problems, or requests for ICT adaptation by the user, must flow back to the global level via the local agent.

There are instances where retailers are unable to source sufficient learning support from within their company and therefore engage the services of people with both practical farm knowledge and relevant ICT skills. These people perform a knowledge translation function and are termed ‘translators’ in this cross case analysis (see section 5.3(d)).

In the Australian market there are also smaller retailers of ICT-based precision dairy technology, including owner-operator businesses. Such retailers interviewed in the scoping study had PDF-CoP links that were more direct than observed with larger retailers. These retailers had an intimate knowledge of their products and therefore were in a better position to engage in knowledge sharing with farmers. In the formative CoP they shaped a co-development relationship with farmers, directly taking feedback and incorporating it in their product. Often the interaction was on an informal basis, consisting of phone conversations and casual on-farm visits. Knowledge transfer of this kind is a powerful mechanism for creation of a flexible and adaptive community of practice where co-learning is a focus. However, it is a double-edged sword with small retailers not benefiting from dealer networks and economies of scale that the larger retailers possess. One small dairy ICT company owner interviewed noted the high economic cost of providing learning support to clients spread over a large geographical area.
The general subsystems which exist within large dairy ICT retailers operating in Australia, as observed during this study, are outlined below.

i) Local agent
Local agents are often the first point of contact with farmers who are contemplating an ICT purchase, and in fact can also fill the role of salesperson. When a farmer decides to invest in an ICT product from their existing dairy technology retailer it often reflects a strong existing linkage with the local agent. This historical linkage is a major asset for the development of a PDF-CoP because it has associated aspects of trust and respect. In this case study, local agents were generally skilled with dairy shed technology, and had a good operating knowledge of farm management. However, in general farmers in the case study and those interviewed in the scoping study perceived local agents as lacking the advanced ICT skills to satisfy the primary ICT user as the users knowledge of the technology grew. Farmers therefore looked elsewhere for this knowledge. The relationship between the local agent and a primary ICT user presents a significant opportunity for development and knowledge sharing as discussed later in this chapter.

ii) Salesperson
The salesperson may be a farmers first link with the retailer, and possibly the first link with precision dairying technology and practice. They are a key actor in the progression from a ‘potential’ PDF-CoP to a ‘coalescing’ stage because they are the link to advancing the idea of ICT adoption to reality. Salespeople are transient in the sense that their role involves linking with the farmer temporarily (during the sale process) however they are extremely important as they influence the formation of ICT expectations and consequently influence farmer goals.

Pre-purchase expectations of farmers contemplating precision dairying technology can relate to both technology performance and learning requirements. Mr and Mrs F had initial expectations that their EID system would identify cows with accuracy very close to 100 percent. Similarly Mr B expected more accuracy from his EID system than was actually achieved in the case study period. Mr D had initial expectations for greater learning support, including training of staff, than he felt was delivered. The formation of these farmer’s expectations can be sourced back
to the pre-purchase phase. At this early point it is the salesperson that holds most knowledge of precision dairy technology and practice, and the pre-purchase phase is where the farmer draws on this knowledge to position themselves in terms of goals and expectations.

### iii) National office

Learning support for the dairy ICT technologies used by farmers in this study was administered at the national level rather than by local agents. Their link to the farmer was either direct, through a trainer, or indirect though a local agent. The national office also formed the key link point between ICT users and the global agent, discussed below. The indirect nature of these links can lead to a knowledge transfer disconnect in the CoP, in contrast to small dairy ICT companies where a strong feedback loop exists. An example was where Mr A wanted the software adapted to allow minor, one-off changes to feed delivery but the update did not eventuate during the case study period:

> ‘They said that they are trying to come up with something like that and that’s probably a year ago since I asked them so I probably should ask them to see whether, they probably haven’t done anything about it.’ (Mr A, January 2007)

Similarly, Mr and Mrs C found it difficult to get a software fault fixed:

> ‘It all depends, from what we hear, how much of a problem they feel it is in other [dairies], if it’s only you well you might have to wait for a long time. If it’s a problem that they find out is in numerous other dairies of the type, they’ll move a bit faster.’ (Mr C, May 2006)

Such disconnections not only frustrate individual farmers but they also have the effect of stifling the exchange of knowledge from the farmer back to the developer. A disconnected knowledge feedback system represents a lost opportunity for constant fine-tuning of ICT to match practical requirements of farmers. If national and global retailers were to view farmers as co-developers of the technology, this would expedite ICT development, and increase integration with farming practice.
iv) Trainer
A subset member of the retailer is the trainer. This CoP member is directly employed by the retailer, and is housed within their operating structure at the national level. The trainer is the direct link between the retailer and the ICT user, in terms of post-installation learning and technical support. They have a formal role, as determined by their employer, to engage with farmers and farm workers using ICT often across a wide geographical area. While they have advanced ICT skills, trainers can focus overly on the material technology at the expense of practical dairy farm management knowledge.

v) Global office
The ICT systems used by case study farmers were all of international origin developed for European and North American markets. Other systems exist which have been developed within Australia but these are not represented in this PDF-CoP scenario. The global office is effectively the ‘home base’ for products of international origin. This is where the development and adaptation of such ICT systems occurs and therefore the existence of an information chain through to the farmer is integral in the design and support of a relevant and quality product. As shown in Figure 5.1, there is generally not a direct link from the global office to the primary ICT user, with information flowing through the national office or local agent.

5.3.4 Consultants
Farmers engage private consultants for a variety of purposes including monitoring financial performance, animal performance and health, analysis of potential investments, and general farm advisory roles. Consultants potentially have a major role to play in a PDF-CoP, however in the case studies this was not being fulfilled. The consultants engaged by case study farmers only interacted with the PDF-ICT systems in a minor way. Their involvement was based around use of collected information to determine feeding parameters. However, they were in a prime position to be more engaged with PDF-ICT, by integrating their in-depth understanding of both the farm and client with knowledge of precision farm
technologies. The potential role consultants could play in a PDF-CoP is discussed in section 5.8.

5.3.5 Translators

Potentially one of the most potent influences on CoP progression is the translator. In the case study, translators were current or former dairy farmers who also had advanced and relevant ICT knowledge, for example Trainer-1b. Similar to Wenger’s (1998) “brokers”, they are highly skilled people spanning different CoP’s to translate, co-ordinate, and realign perspectives. Huggins (2000) identified brokers as go-betweens who bring people together, and defined them as negotiators who facilitate communication, access to information, and exchange of knowledge amongst network members. In the PDF-CoP a translator has the specific ability to bridge and translate between the two different tacit knowledge forms of farm management practice and sophisticated ICT use. Their capacity to stand in both worlds also engenders legitimacy from members. In the case studies, translators were either engaged by the retailer as a subcontracted training instructor, or directly by the farmer. Respected peers, discussed below, can be very similar to translators but are primarily differentiated by less formal links to the ICT user and lower ICT understanding.

Through identification and use of people with these skills, learning networks can be established within a community of practice. While translators are potentially a powerful tool for retailers to utilise in their learning support structure, there are also risks associated with relying on translators to deliver training packages. While a technician is employed to perform certain learning support duties, translators may decide at any time to cease their training role due to changes in their personal goals or work demands from their own properties. Mrs C provides an example of a translator. She was subcontracted by a national ICT retailer to support other users in the area, but if she was required to spend more time on the farm then she would become unavailable for training and the retailer would need to fill the gap. Reliance of retailers on using translators for client training potentially impacts on the resilience of their learning support programs.
Case study farmers also noted that, although translators could act as a bridge between two knowledge forms, this did not necessarily mean that they were adept at facilitating learning. Mr B stated that the translator employed to teach him “spoke too fast and showed things too quickly”. The training focus was on providing farmers with knowledge on PDF-ICT use, rather than empowering farmers to be self-managing reflective learners. This approach has implications for the rate of PDF-CoP evolution due to limited fostering of innovation and knowledge creation.

5.3.6 Respected peers

Farmers often learn from other farmers whom they respect (Kilpatrick & Johns 1999), using the experience of others as informal performance benchmarking. These respected peers are mostly used in the PDF-CoP in the ‘potential’ stage, where a farmer is investigating use of ICT in their management by reviewing how other farmers are applying it. The opinion of respected peers holds significant weight at this stage, often guiding farmers toward certain products which receive good reviews or warning them about early implementation issues.

Viewing case study observations through the community of practice lens highlights the areas where learning networks were strong or were underdeveloped. Some case study farmers did discuss issues with respected peers as the CoP reached a more mature stage, for example Mr and Mrs F discussed the issue of data transfer with a friend who was experienced with software writing. Mr B also approached a friend he perceived to be an ICT expert with a similar query. However, there was limited opportunity for any of the case study farmers to interact with other ICT users. The reason for this undeveloped linkage is two-fold: firstly precision dairying as a farming practice is still in its formative stages and therefore few farmers have engaged with it; and secondly the current learning networks among those farmers who are using precision tools and practices are not strong. The potential expansion of the inter-farmer relationship is discussed later in this chapter.

Farmers in the case study had little opportunity to learn directly from other primary ICT users, representing a lost opportunity for knowledge transfer. This also placed
more emphasis on the ability of retailers, as the main link between users, to receive feedback from primary ICT users to enable transfer of this knowledge to other farmers. This interaction fits within models of the professional advisory relationship, such as those outlined in section 3.2.3. The model of Paine et al. (2004b) focused on the creation of a ‘learning partnership’ based on understanding a farmer’s actions, intentions, and worldviews. An example from the case study of where a learning partnership may have aided the development of a precision dairying system is the experience of Mr B. A learning partnership framework could have been constructed by explicit discussion between Mr B and the retailer early on with the purpose of exploring Mr B’s management style, intentions for the technology, and worldview, and marrying these factors with the retailer’s commitment in regard to technology performance and learning support structure.

Retailers represent a key link in facilitating knowledge transfer between farmers and it is therefore vital that the advisory relationship is strong and open to two-way (farmer to retailer) knowledge flow. By viewing their interaction with ICT users in terms of a learning partnership, retailers could open the door to two-way knowledge flow, creating a stronger and more resilient PDF-CoP.

5.4 Community of practice – stages of development

Lave and Wenger (1991) proposed that new members move from peripheral participation to core participation via involvement in a CoP. This transition occurs through individual change manifested as development of the CoP as a whole. According to Wenger (1998) a CoP can progress through five possible stages: potential, coalescing, active, dispersed, and memorable (see Chapter 4). In this section the experiences of case study farmers are related to the first three stages of Wenger (1998). The fourth and fifth stages involve members in mature communities of practice undergoing disengagement and diminished interaction. These stages were not relevant to the emerging precision dairying systems observed in this study and are therefore excluded from the discussion.
Using data from the case study to examine the stages of CoP development highlights important actors and events in the evolving learning network. The analysis helps identify strengths and weaknesses in the developing PDF-CoP and points to areas for improvement. The stages of CoP development reflect the emerging precision dairy farming systems, where negotiation and co-development between members are key to creating linkages and defining roles.

### 5.4.1 Linkages begin to form in a potential PDF-CoP

In this initial stage of the PDF-CoP, individuals are acting on their own or with only minor linkages to others. They are therefore unable to benefit from shared knowledge gained through interaction with other individuals. It classifies as a potential CoP because these individuals are separately beginning to learn, each with the same core goal of developing precision farming practice. Through necessity or serendipity these individuals begin to find each other and form links based on the commonality of their goal (Wenger, 1998).

In the case study, individuals began to link with others during the pre-purchase process. All participant farmers identified a need to increase control over variable production factors on their farm and therefore began to investigate strategies to achieve this. Farmers such as Mr A and Mr B began forming links by contacting respected peers or retailers (local agents). Farmers may also use respected peers to develop their goals and values associated with precision dairying. For example, they may first hear about the concept while talking to a neighbour. Before they purchased their ICT system, all of the case study farmers visited other farms which had such systems already operating and sought the opinions of other farmers of their systems. These interactions were generally a one-off event.

The retailer, and in particular the salesperson, is an influential figure in this stage of the CoP. It is at this point that farmers develop expectations of their role in the CoP via discussion with other members, notably the retailer, and through subsequent reflection against their personal goals and values. The goals and
expectations developed at this formative stage of a precision dairying system can significantly impact the future functioning and resilience of the CoP, as highlighted by Mr B’s experience with unmet expectations and subsequent disconnection with the retailer.

5.4.2 Members are drawn together in a coalescing PDF-CoP

The CoP begins to take shape as links form between PDF-CoP members. In this coalescing phase, members recognise the potential of other individuals and link them into the community (Wenger 1998). According to Wenger (1998), key features of this phase include exploring connections and negotiating roles and structure within the community.

A coalescing PDF-CoP was illustrated in the case study by farmers taking the next step in PDF uptake, and searching for connections with other people to help them learn and adapt to the new practice. At this point they had already decided on a system, installed it and began using the individual cow data in their farming practice. A feature of the case study farms in this stage of CoP development was the initial loss of system control, despite the aim of precision dairying being to increase system control. Soon after installation, Mr A experienced an unprecedented mastitis outbreak, Mr B’s herd also developed mastitis and had an incidence of severe acidosis, and Mr D struggled with technical faults and creating efficient systems.

Each farmer reacted to the loss of control differently, and each differed in their interaction with the community of practice which was forming around them. Mr A relied heavily on his own knowledge, augmented by that of his consultant and the ICT retailer. Mr B also used his own knowledge and that of his nutritionist. The interaction between Mr B and the ICT retailer was divergent, rather than a two-way learning partnership. Mr D, however, created more of a learning partnership with the ICT retailer by suggesting possible ICT adaptation and also acknowledging his role as a co-developer.
The precision dairy systems studied reflect an industry in an immature stage in Australia and a feature of the coalescing stage involves community members confronting the equivocality inherent in the new practice. As a consequence there were gaps in the knowledge base held by individuals (farmers and retailers) on specific problems that occur during adaptation of the technology into farming systems. In the coalescing PDF-CoP these knowledge gaps were overcome through transfer of knowledge between retailer and farmer. An example of this is provided by both Mr B, and Mr and Mrs C who encountered retailer scepticism regarding the cause of technology adaptation issues:

‘There are glitches in the software, and it's taken ages to get them to acknowledge that it's a problem. They come out and try and fix it, they won't tell me what they're fixing, tell me what they've done for fear of actually admitting that there's a fault in the system.’ (Mr B – September 2006)

‘Mr C: It takes a while to actually get past, make them acknowledge that there is a problem, as far as the feeding one it took a long time and it did take a while.
Mrs C: Because we kept saying to [the technician] it's doing this, [he said] oh no it can't be.
Mr C: But it was doing what we were saying.
Mrs C: Because their first theory to everything is operator error, but it's not [the reason].’ (Mr and Mrs C – May 2006)

These scenarios represent the equivocality in the coalescing CoP, where members have multiple interpretations of the problem. Weick (1990) states that communication cycles between members can be used to find a pre-eminent explanation of the equivocality. However, the communication cycles between CoP members were sometimes disconnected and/or represented one-way flows rather than cycles. In Mr B’s case the negotiation of roles in the CoP foundered due to incomplete connections. In the examples above, case study farmers struggled to have their interpretations of the problem heard due to the pre-determined judgement held by retailers of the cause of the problem. More open
communication cycles were required in this stage of the CoP to enable efficient and effective explanation of equivocality.

5.4.3 Roles are refined in an active PDF-CoP

Once the basic framework of the CoP is constructed, it reaches a more stable and functional period termed the ‘active stage’ by Wenger (1998). In this stage Wenger (1998) states that CoP members engage in developing practice though joint activities, interacting and sharing knowledge to facilitate adaptation of concepts and practice, creating artefacts, and continually reconstituting the nature of both the inter-relationships and the CoP as a whole.

In this active stage, case study farmers developed practice by identifying people who filled their specific needs, and forming stronger links with them. Mr and Mrs F, and Mr D, provided clear examples of this. Not all farmers had a choice of people to approach for help. Mr E had no local retailer and only one national technician. As the only user of that particular ICT system in Australia he could not look for peer support. In a small and formative CoP such as in this study there would be real merits in linking precision dairy farmers, and trainers, across ICT products, and facilitating the sharing of knowledge based on general principles rather than product-specific discussion.

The creation of artefacts is an important feature of active communities of practice. In the precision dairying community, artefacts included learning resources such as formal ICT user manuals compiled by the retailer. Other, less formal, learning resources were derived from the experience of ICT users, such as Mr and Mrs C who constructed a trouble shooting guide for milking staff to use. *Trainer-1b* also created a more farmer-friendly manual with step-by-step instructions. Naturally, artefacts that record explicit CoP knowledge are only useful if they are in a form applicable to members. These useful forms are more likely to include practically focussed guides as opposed to formal and descriptive software manuals.

Software reports also constitute an artefact for recording explicit knowledge on key decision making trigger points. PDF-ICT software includes pre-loaded
standardised reports, for example identifying cows due to be dried off. Case study farmers adapted these reports to their specific farm practice, or created new reports. Such adaptation represents a key knowledge artefact which could be of benefit to all community members. However, in the case study, any knowledge transfer occurred via trainers or translators rather than from farmer to farmer. On farm software adaptation, such as report construction and modification, represents a valuable source of knowledge development not only for other ICT users but also for global retailers seeking to enhance their products. It is therefore vital that the PDF-CoP links facilitate sharing of such adaptation.

Interviews with PDF-ICT users in the scoping study phase provided an insight to the appearance of learning networks with a PDF-CoP more than two years after installation. The communities around these farmers began to represent a more dispersed stage (Wenger 1998) as linkages to other members (retailer, translator, respected peer) diminished in strength. Farmers in this stage were competent with PDF practice and did not perceive a need for further reflective learning resources. Artefacts created in the active stage also became redundant due to the information in them being internalised into the farmer’s tacit knowledge. Maintaining a relevant community of practice, and therefore fostering ongoing learning past the installation and adaptation phase, is beyond the responsibility of ICT retailers and is better matched with a dairy industry initiative.

5.5 Facilitating linkages between community members

Vitality in a community of practice is dependant on the presence of appropriate people to stimulate knowledge creation, as well as strong linkages between people to facilitate knowledge transfer. Analysis of experience of case study farmers highlights several linkages between PDF-CoP members that are the key to a vital and resilient community. CoP members are effectively co-developers of precision dairy practice and knowledge, and this co-development role is emphasised in the discussion below.
Primary ICT user to salesperson:
The linkage between farmer and salesperson is only temporary but it is highly important because it involves the formation of initial expectations of PDF technologies and practice. The salesperson can be the first link for farmers with precision dairy technology and practice. Communication cycles are initiated in the process of fitting material technology to the farmers goals. These goals for precision dairying can be blurred by limitations on expenditure and misconceptions surrounding technology performance, adding to the equivocality of the pre-sale process. Salespeople therefore have a responsibility to facilitate communication to build the farmers knowledge of precision dairy practice to a point where he/she can more accurately judge the likely benefits of investment. Results from the case studies indicate this communication currently takes place, but that more could be done to co-develop precision dairy knowledge at this early stage.

Primary ICT user to local agent:
The local agent to user linkage is currently under-utilised. Local agents often can engage with farmers with credibility and legitimacy because of their working knowledge of dairy systems, and they can physically visit farms more easily than national-based trainers. Currently however many local agents do not have the ICT skills to solve anything more than basic ICT queries for users. Greater skill development of local agents would prove very beneficial for rapid one-to-one ICT knowledge transfer. The current small dairy ICT market is a barrier for such up-skilling because not only is it difficult for local agents to justify the learning investment, they may also struggle to maintain competency due to a lack of opportunity to apply their skills. Local agents are also technically minded because their primary role is to install and maintain dairy shed technology such as milk lines and vacuum pumps. ICT and the use of information in decision making is outside their traditional sphere of knowledge and building skills in this area is a challenge.

This represents a capacity-building challenge for retailers, which they have attempted to address by running ICT workshops for local agents. However, the skills learnt are often forgotten by local agents due to lack of regular interaction with the ICT systems. Adopting a co-development mindset and aiming to learn
from the farmers would help local agents to remain engaged with software use and also pick up techniques and tips that could be passed on to other farmers.

**Primary ICT user to global office (via national office):**

In the case studies, the link between end user and ICT developer (the global office) did not facilitate a simple transfer of knowledge. This link is important because it provides the means for a feedback loop for the developer in regard to how ICT is actually being used and where potential problems exist. The ongoing development of ICT products depends upon adaptation of technology as a result of user feedback. Currently the national office acts as a gatekeeper in this process: either offering to provide user feedback to the global office, or releasing adapted ICT back to the user after development by the global office.

The weak link between developer and user is in part due to the international origin of the ICT used by case study farmers. For a farmer seeking to have a problem fixed, the first point of contact is the local or national retailer. However these CoP members are only able to undertake simple ICT adaptation and more complex requests are sent to the global office which may wait for more evidence that investment in adaptation is required. Appropriate evidence generally involves an assessment of consumer demand, therefore if only one farmer requests a specific update the developer may decide to postpone the adaptation investment.

The need for a stronger linkage between ICT user and global office is especially important due to the early ‘active’ stage of the PDF-CoP in Australia. Australian dairy farmers implementing ICT products originally designed for international dairy systems are finding that some adaptation is required. Case study farmers who had used Australian-designed ICT previously, such as Mr D and Mr & Mrs F, found local developers much more responsive. Leeuwis (1993, p.168) suggested ICT be developed in a more iterative process, where there is a high degree of user participation and acknowledgement that information needs of the user often evolve as their ICT experience grows. While the ICT systems used by farmers in this case study have been available for over a decade, their implementation into pasture-based dairying systems in Australia can still be viewed as representing a ‘prototype’ stage. This is indicated by the challenges facing many farmers in this
study such as EID misreads, software glitches, and unforeseen requirements for practice adaptation. Linking on-farm experiences of users to ICT system development in the global office can aid in bridging the gap between ICT design and practical farm use.

**Consultant to primary ICT user and retailer:**

PDF-ICT and the precision dairy concept fit well with a consultants objectives of increasing their clients productivity through enhanced control and efficiency gains. Daily information on cow production and health is relevant to nutrition consultants in particular. Private consultants were not directly linked into the PDF-CoP of case study farmers. Mr B stated that his nutritionist knew how to use the PDF-ICT software but chose to use another dedicated nutrition program for feed allocation decisions. Mr E's consultant also interacted with the PDF-ICT software but again preferentially used another program for nutrition planning. An opportunity exists to strengthen the role of consultants in the community at two levels. The first is through increased interaction between primary ICT users and consultants around the technology. This would essentially involve greater use of PDF-ICT tools by consultants, and co-development of PDF knowledge with the farmer. The second involves increased interaction between consultants and retailers. An important factor in knowledge expansion within a CoP is the extent to which existing knowledge is challenged and the process by which contradictory information is resolved. The challenging of established ‘assembly rules’ (Weick, 1969) is essential in the creation of new knowledge. Greater involvement of people such as consultants and translators potentially creates an environment of contestability which could be either constructive or harmful to functioning of the community.

Potential contestability surrounds the setting of grain feeding rates for individual cows. If different members of the CoP have opposing views on the use of ICT for driving individual feeding rates final responsibility lies with the farmer to choose the best approach. PDF-ICT systems often have their own in-built feeding model to guide feed decision-making while nutrition consultants also have specific feed allocation methods based on separate nutrition models. Nutrition consultants might dismiss the suppliers model in favour of their own, or they might attempt to recalibrate the PDF-ICT model to account for farm specific factors. Inclusion of
consultants in the CoP therefore presents a double-edged sword situation: increased contestability and challenging of assembly rules within the community could lead to either facilitation of knowledge creation or an environment of conflict where contradictory information (such as a suppliers feeding model) is disregarded.

Primary ICT user to translator:
The importance of knowledge transfer between farmer and translator has been discussed earlier in this chapter. A current weakness is the lack of translators available to join the PDF-CoP. There are few people currently able to bridge the two domains who also have the time and inclination to perform the translator role. Translators represent a prime opportunity for national retailers struggling to cover a geographically spread client base. A focus on building capacity of ‘switched on’ farmers using ICT to train others could be an efficient solution to the current struggle to provide farmer training and support.

Primary ICT user to primary ICT user:
A link not discussed in this PDF-CoP model is the potential interaction between active users. In a multiple farmer model this link would be similar to an ICT user contacting a respected peer or a translator, differentiated because the respected peer is another active user with whom the ICT user shares knowledge. The linkage would be of an informal nature, as opposed to the more formal contact with translators. Such an interaction could be a powerful resource in the PDF-CoP due to the transfer of highly practice-based PDF knowledge; however, based on the experience of case study farmers, this linkage is virtually non-existent. The small size of the PDF community is part of the reason for the lack of such links. Dairy farmers using PDF, and especially those linked by the same retailer, are often spread over large geographical distances making it difficult to interact. Some retailers organise user group sessions which may serve to link farmers with common interests, however user groups are sporadic and often ill-attended. Retailers have the option of acting as a knowledge conduit between users, for example by publishing a user newsletter that includes a section on actual farmers precision dairy practice.
5.6 Benefactors of a strong PDF community of practice

The PDF-CoP initially forms based around the foundation members, the primary ICT user and retailer. At present new members are drawn into the community essentially at the behest of a foundation member. Does this mean that the foundation members are responsible for fostering and maintaining a PDF community? The answer lies in identifying the parties benefiting from a strong PDF-CoP. In this section it is argued that foundation members benefit, along with the dairy industry as whole.

The first obvious benefactor is the individual farmer practicing PDF. As seen from the case study farmers experience, the effective application of PDF results in increased system control through labour efficiency gains, targeted use of high value supplementary feed, increased timeliness in individual cow management, and enhanced risk management practice. Farmers also receive other benefits, such as creation of identity through the application of ‘leading edge’ practice. An example of this was Mrs C who became an ICT ‘expert’ through the course of the case study, culminating with the retailer engaging her in a consultancy role.

Retailers fundamentally benefit from a strong PDF community through increased sales as precision farming is founded on the use of data collected via information technology. Increased sales flow from introducing farmers to the PDF-CoP. A strong PDF-CoP provides potential entrants with confidence from a strong support network. The enhanced knowledge and increased PDF-related benefits created by the community also provide evidence of a return on investment for farmers. In addition to increased sales, retailers may also benefit from a more efficient learning support process. If ICT users have multiple links for their learning experience (including other users, translators, skilled local agents, and knowledgeable consultants) they are less likely to ‘lean on’ retailers for basic learning support.

The third major potential benefactor is the dairy industry. The PDF-CoP discussed in this chapter highlights the lack of input from industry representatives such as
extension agents and researchers. There is considerable opportunity for these representatives to play a part in fostering precision dairying practice and this is further discussed in the next section.

5.7 An industry-level community of practice

The precision dairying community of practice outlined in this chapter has focussed on the learning and knowledge sharing network around individual farmers in the case study. However, the networks actually link individual farmers and retailers at an industry level. Figure 5.2 illustrates the industry level networks, along with community members and linkages that currently don’t exist.

Absent community members

In viewing the PDF-CoP in an industry context it becomes clear that the main players are either product retailers or farmers as technology users. The community currently lacks members such as researchers and extension agents who are present in other aspects of dairy farm management such as nutrition or grazing management. This presents a capacity building challenge at the industry level in terms of funding and promotion of these absent members. This has begun to occur with projects such as Future Dairy based at The University of Sydney (Garcia et al. 2007) but there needs to be more emphasis on farming practice. This involves guiding precision dairy farmers on the adaptation of technologies into their specific systems, and adding to the community knowledge on how to best use the on-farm data collected.

Inter-retailer linkages

The industry PDF-CoP depicted in Figure 5.2 highlights the lack of knowledge flow across different retail companies. Retailers acted as primary links between farmers in the CoP observed in this study, but that model limits knowledge flow only among farmers using the same product. This represents a form of privatisation of knowledge (Paine et al. 2004a), where knowledge about precision dairying practice is locked up by individual firms. One of the potential impacts of knowledge privatisation is reduced innovation (Paine et al. 2004a), and aspects of this were
observed in the case study. For example there was no pathway for Mr E to learn of the advanced precision dairying practices of Mr D because they used different products and lived in different states.

General operating principles behind each PDF-ICT system are similar, and consequently the general adaptation and use of different products is also comparable. Therefore an alternative pathway for knowledge transfer between farmers is through the retailer, regardless of brand type. Naturally opportunities for different retailers to interact is limited, and the exchange of knowledge would be hampered by commercial confidentiality, but not all knowledge learnt by retailers as part of their community links should be viewed as proprietary knowledge. Transferable knowledge may centre on promoting retailer best practice, and developing inter-operability and data exchange between products of different companies. Retailers require an incentive to commercially justify the time and resources for creating and maintaining such knowledge transfer structures. A vibrant community, with easy access to knowledge, would be more appealing for farmers considering precision technology and could help expand the retailer’s client base.

*Industry opportunities for data exchange*

Major opportunities for seamless exchange of data and knowledge via integrated ICT networks potentially exist in a whole of industry PDF-CoP. Data collected on farm could be transferred to industry databases using the internet. An example is the collation of on-farm data on individual cow production to be used at an industry level for herd improvement purposes. With dairy farmer participation in Australian herd improvement (HI) schemes decreasing (ADHIS 2005), the collation of milk yield data may be the key to their survival. Linking precision dairy farmers could also build an information-rich industry database for use in benchmarking or industry output predictions.

Conversely, without a streamlined and trouble-free data transfer system from the farm to the HI centre, increased use of precision dairy practice may lead farmers to desert the HI scheme. This was observed across the scoping study and case study, where several farmers either reduced the number of herd tests they
undertook, or ceased them completely. The drivers behind this change included labour saving and perceived irrelevance of HI data when daily milk yields and conductivity were already collected. Furthermore, of those who had maintained their HI tests, many did so primarily for the data on somatic cell count. With in-line somatic cell sensors close to a commercial reality (Whyte et al. 2004; Miglior et al. 2006) this may induce more farmers to forego HI tests in favour of their daily on-farm data sources.

Herd improvement organisations did play a role in the PDF-CoP observed in this study, as indicated in Figure 5.2. Case study farmers such as Mr and Mrs C sent average seven-day individual milk yields to their local HI centre. Their experience is indicative of many:

‘The last one [herd test report] was okay, the last month was fine. The one before Christmas we were absolutely disgusted we were tossing up the idea of not doing it. Just keep our own records, because they mucked up our records, the cows that we sent milk for they didn't send us any fat or protein or any, they had the numbers but nothing next to them.’ (Mr & Mrs C, February 2007)

The link between precision farmers and HI centres was observed to be problematic, primarily due to issues with incompatible software and data transfer formats. There were issues with retailers protecting their proprietary systems, and HI centres not being equipped to deal with herd data from sources other than their own. Regardless of the specific reasons, the lesson is clear: industry organisations need to become more proactive in the PDF-CoP to ensure the data and knowledge flow from, and back to, farmers is maximised. Increased use of precision dairy farm practice in the Australian dairy industry will see farmers creating and holding significant intellectual property. Without an incentive to pass on this knowledge, the wider industry will incur an opportunity cost.
5.8 Interventions to foster and maintain a PDF-CoP

Wenger (2004) stated that CoP’s are social structures focussed on knowledge which explicitly allow knowledge management to be placed in the practitioners hands. In the case of the PDF-CoP, who exactly are the practitioners? In the model developed in this chapter there were multiple practitioners: the farmers; retailers; and to some extent the translators when they are engaged as consultants. According to Wenger (2004), practitioners are the ‘carriers’ of knowledge and they can directly test new ideas. Under this definition, farmers, already identified as the centre of a PDF-CoP, are the key practitioners because they are able to directly test new ideas that result from community interaction.

Retailers may not have been able to directly test ideas through farm management adaptation, but they served a major role as ‘hubs’ for knowledge management in this study. The practical PDF knowledge gathered by farmers needs to be shared with the community if the community is to evolve. The link between farmers and the retailer has to facilitate knowledge flow back to the retailer via what Wenger termed a ‘knowledge extraction’ process. Knowledge extraction expedites the

![Diagram of linkages between members of an industry PDF-CoP](image-url)
development of precision dairy practice throughout the dairy industry, and increases the rate of adaptation and development of precision tools themselves.

While individual farmers are at the centre of the community they may struggle to find the motivation or means to expend time and energy fostering CoP growth beyond their own immediate needs, especially if they see no direct benefit to their business. Retailers and industry representatives are in a more powerful position to facilitate knowledge extraction and management with greater cross-linkages to other farmers and CoP members. Wenger (2004, p.5) identified that "involving practitioners in knowledge management is also important for returning knowledge from the field". Methods for creating cross-linkages and ‘returning knowledge’ could include forming more user groups and initiating an email forum for practitioners of all levels, or via other means such as newsletters.

Another key in knowledge management and maintenance of a CoP is the avoidance of ‘organisational silos’ where knowledge is accumulated by particular people (Wenger 2004). Silos can occur within the farm, for example where a worker is the primary ICT user, or elsewhere in the CoP, such as a trainer who represents a retailer’s ICT knowledge bank. While they are not inherently problematic, the risk arises if the worker leaves the farm or retailer, taking their knowledge with them. Avoiding knowledge silos is difficult, especially in a small market such as PDF-ICT where the expense of investing in multiple learning-support technicians cannot be justified by retailers. Reification, involving converting tacit to explicit knowledge in the form of artefacts, can be used as insurance against the loss of silos (Wenger 1998). This would involve creation of practical manuals, or dissemination of knowledge through newsletters or email forums. Alternatively (or concurrently) fostering participation of more members in the knowledge creation process prevents large amounts of knowledge being stored by one person.

Nurturing a PDF-CoP relies on attention to the three elements of domain, community, and practice (Wenger 2004). Domain, relating to the underlying area of knowledge driving the community, can be nurtured by explicitly acknowledging and continually negotiating what the community is about. A PDF-CoP is not about
hardware and software as they are just a means of collecting information. The domain concerns the use of fine scale information to increase management control of variable farm factors. Emphasising the importance of information management in negotiation of the CoP domain will focus community members on information rather than specifics of technology. This emphasis should occur throughout all stages of precision dairy system development. For example in the pre-purchase phase there should be a focus on the potential applications of the information collected, including use of specific examples of management practice adaptation.

Nurturing the element of community in a CoP depends heavily on strengthening the relationships between members, and attracting new members to fill knowledge gaps. The PDF-CoP involved a broad range of members who never assembled together in person, highlighting the importance of inter-member links and knowledge flows. The important linkages, as discussed previously, included: facilitating an enhanced feedback loop between user and developer; greater use of local agents; and redeveloping the user to salesperson link. Consultants could also play a greater role in the community, achieving a similar purpose to translators by linking knowledge of ICT with specific farm knowledge. Expanding their role involves linking them to retailers, and inviting them to training sessions. Retailers would benefit from consultants assuming the role of learning support and data managers because it frees up the retailer to focus on installation and higher level support.

Researchers and extension staff were also missing from the PDF-CoP model. Introduction of these members into the community is dependant on promotion (and funding) at the dairy industry level. This requires recognition of precision dairy practice, or information intensive management, as a discrete facet of management, at the same level as other facets of management such as animal nutrition or grazing management.

Improved practice results from development of social capital, the nurturing of new knowledge, and ability to share tacit knowledge. Many of these issues have already been discussed in this chapter, and are highly dependant on attention to the two factors of domain and community. A key driver for knowledge expansion
within the CoP is the ability of members to reflect on and question current practices. Increased involvement of consultants and researchers would aid this reflective process; however care also needs to be taken to ensure contradictory information is resolved in a manner beneficial to community practice, rather than being a source of conflict and disconnection. Ongoing reflective practice would also assist in maintaining relevance of the CoP for more experienced precision dairy farmers who know the fundamentals of ICT and are seeking new knowledge and continual improvement in precision dairy practice.

5.9 Summary of key learnings

Precision dairy systems currently represent a minority of farms in the Australian dairy industry. While this emergent concept generally doesn’t constitute a radical shift in management practice, its information intensive nature does present challenges for learning, knowledge management, and knowledge transfer. The precision technology offered by dairy equipment retailers focuses on devices, rather than presenting an integrated system. In contrast, farmers commonly think they are purchasing a system where only basic learning is required and much of the development has been completed. Currently, farmers and retailers are effectively co-learners in this emerging farm management concept. Key learnings from Chapter 5 are summarised below.

- The actors in emerging precision dairy systems should be viewed as members of a knowledge creating community, based around the specific goal of using precision technologies to achieve greater control over variability and risk in dairy systems.

- Precision dairy farmers need to be considered as co-developers of precision dairy systems, along with the retailers and other members of the community of practice. Retailers must acknowledge this co-development role in both material technology refinement and in creation and transfer of practice-based knowledge on precision dairy practice. The explicit inclusion of farmers as co-developers requires retailers to move away from the mindset that their products are ‘one size fits all’ plug and play technologies. Instead the products should be
promoted as technology systems which will be adapted into particular farming operations, with an emphasis on communication cycles with the farmer as precision dairy practice is implemented on the farm. In this way, inevitable ‘bedding in issues’ during the early months of operation can be perceived by both farmers and retailers as a natural part of adaptation to precision dairy technologies.

- Capacity building can be enhanced by strengthening the learning networks between key members of the community, also improving the knowledge flow between farmers, retailers, and other people such as translators and consultants. Improved knowledge transfer will also avoid problems with knowledge silos where key members of the community, such as trainers, possess specific knowledge that could be lost if they leave the community. The increased use of translators, to bridge the tacit knowledge divide existing between practical farm management practice and specific ICT functionality, could also aid knowledge transfer as well as helping to build a more resilient training network.

- The community would benefit from the development of more members who perform knowledge management functions. Knowledge managers possess social and organisational capabilities, in addition to having technical PDF-ICT skills. Retailer trainers were criticised by case study farmers for being too heavily focussed on technical skill and struggling to relate to farm management practice. In this case study, the translators performed the task of knowledge managers, with the ability to bridge between PDF-ICT and farm management. In doing so, they were also able to convert tacit knowledge forms on both sides into an explicit form enabling knowledge transfer to farmers and retailers.

- While the ability of translators to convert ICT and practical farming knowledge proved invaluable, the case studies also highlighted a lack of a focus by retailers and translators on empowering farmers to self-manage their own learning. The provision of a step-by-step manual was extremely useful to farmers wanting a quick guide to PDF-ICT use, however it did not dramatically build on the farmer’s knowledge of the PDF-ICT system in general. This was
also the case where trainers would construct ICT-based reports on request and email them to the farmer. Again farmers found this service useful because it reduced their learning effort and time, but it did not improve the farmers ability to construct such reports in the future. Prescriptive training limits farmer innovation and knowledge creation because it restricts reflection on the assembly rules used for certain PDF-ICT functions and the potential applications for PDF-ICT in farm management practice.

- Viewing the precision dairying community of practice at an industry level highlighted a need for greater emphasis on networks that facilitate the flow of data and information. Formal networks are required to ensure the wider dairy industry can gain from the vast amount of data collected on individual precision dairy farms. Informal networks form the basis for knowledge transfer surrounding best precision dairy practice. Farmers in the precision dairy community have little opportunity to interact and share knowledge and it is in their interest, and the community of practice, that informal interaction opportunities are enhanced.

- The PDF-CoP provided a network within which learning processes developed and knowledge was created and exchanged. Learning processes of precision dairy farmers differ as the PDF-CoP evolves. The rate of change in the community of practice, and in the learning processes themselves, can provide a more tangible indication of the success of knowledge creation and innovation within a community. The CoP that evolved around individual farmers in this study progressed to an active state, but disconnected knowledge links and absent community members meant that there was significant unmet potential for further development of precision dairy farming systems. Enhanced uptake and utilisation of precision dairy farming practice is dependant upon strengthening the learning networks around farmers and encouraging an environment of knowledge transfer and continual reassessment of the assembly rules governing the precision dairy concept.
6. How much precision is enough? On-farm construction of precision dairy systems

6.1 Introduction

Precision dairy farm systems focus on improving management control over variable farm resources. At the heart of these precision systems is objective and timely data, collected through use of information communications technology (ICT). In previous chapters the learning experiences of six farmers during the installation phase of precision farming technology were analysed. Observed practice of the case study participants indicated that farmers would make trade-offs between data quality, data quantity, and learning load associated with PDF-ICT.

In this chapter the underlying factors driving a farmer’s construction of their precision dairy system are investigated. The question is asked ‘how much precision is enough?’ in order to fulfil the goal of gaining control over variable farm management resources. The adoption of advanced precision dairying systems is currently low with under ten percent of Australian dairy farms using the technology (Miglior et al. 2007). Farmers have limited time and money to invest in precision dairy systems and these constraints can act as boundaries around their purchase decision and subsequent use of the technology. This chapter focuses on the construction of precision dairy systems from a user perspective by examining trade-offs farmers make to balance investment in material technology and learning with their enterprise constraints. The outcome of this study is an increased
understanding of the processes behind dairy farmers’ engagement with precision dairy systems.

Chapter 6 begins with insights from farmers previously interviewed in the scoping and case study phases. Based on these insights an additional study is described which specifically examined the factors affecting construction of precision dairy systems from an experienced users perspective. The implications for construction of precision dairy systems into the future are discussed at the end of this chapter.

6.2 Designing a precision dairy system

6.2.1 Introduction

Dairy farms are among the most complex of agricultural production systems, requiring continuous (daily) decisions about inputs and management practices. There is also a vast range of information farmers use to guide their decision making including milk production, fertility, feed production and usage, animal health, labour inputs, and prices. Precision dairy systems constitute a response to this complexity and variability by collecting data at a frequency and scale which enables the farmer to achieve greater system control.

Precision dairy systems are founded on ICT and can require significant capital investment in technology which has inherently high depreciation. The capital cost of precision dairy technology was identified by dairy farmers and ICT retailers interviewed earlier in this study as being a deterrent to further investment. Results from the case studies described in Chapter 4 also highlighted the indirect costs associated with learning to use new ICT technology and in learning to integrate the collected data into farm management practice.

Technology-push from researchers and retailers, rather than technology-pull from farmers, has been a feature of the precision farming domain. To date there is little published research aimed at identifying the farmer-specific requirements for design of precision dairy systems. Potential information needs and potential information
technology use on Dutch dairy farms were investigated by van Asseldonk \textit{et al.} (1999b) but their approach of using ‘dairy IT experts’ failed to ascertain the perceived needs of dairy farmers themselves. Precision livestock farming research currently focuses on technology development associated with data measurement on livestock farms (Berckmans 2008) but how much data do farmers currently need, how often do they need it and how precise does it need to be?

### 6.2.2 An example: accuracy for in-line milk meters

Premium quality in-line milk meters are the most expensive items in a PDF-ICT system. They are engineered to comply with accuracy guidelines set by the International Committee for Animal Recording (ICAR). These standards are in place to ensure data from monthly herd recording programs has statistical validity for bull proofing. However, Koorn (1998) found that daily milk yield measurement from less precise in-line sensors still achieved ICAR standards due to increased frequency in data collection.

A day-to-day variability of 6.8\% coefficient of variation (CV) has been measured in dairy cow milk production, calling into question the need for meters with an ICAR-stipulated measurement precision of 2.5\% CV or less (Clarke & Hannah 2007). Assuming a daily variation of 6.8\% CV, 95\% of cows averaging 20 litres per day would produce between 17.3 - 22.7 litres/day (Mein \textit{et al.} 2001). A meter of 7.5\% CV would still detect changes in milk production of over four litres/day, accuracy suitable for daily management use. With such natural daily variation in cows the use of less accurate milk meters, with increased frequency of data collection, was shown to achieve similar levels of precision to less frequent collection of high accuracy data (Clarke & Hannah 2007).

Given the natural daily variability in milk production, many farmers consider that daily data collected via PDF-ICT systems and used as multiple day averages is more accurate than the 24 hour values collected every 4-8 weeks by herd improvement organisations (Miglior \textit{et al.} 2006). This perception is supported by participants in the scoping study and case studies in this project. Mein \textit{et al.} (2001) stated that use of simpler meters, with a precision of 7.5\% CV, would result in price
savings encouraging uptake of PDF-ICT systems and allowing farmers to invest in ‘absolute reliable cow identification’. This was reiterated by Clarke and Hannah (2007) who stated that use of less precise meters could lead to a subsequent increase in performance recording, potentially providing more data for progeny testing.

A similar argument was put forward by Barioni et al. (1997, in Parker 1999) in respect to use of pasture measurement tools on dairy farms. They quoted research indicating farmers would receive no economic advantage from improvements in pasture mass measurements to reduce the CV to below 20%. As tools such as the rising plate meter (RPM) already match or exceed this level of accuracy Barioni et al. (ibid.) suggested that future research should be directed into developing tools with increased simplicity which save time in measurement and interpretation. They also predicted that over-investment in other farm monitoring technology was likely into the future.

Reducing unnecessary investment in technology development requires an assessment of user needs and potential end uses. Farmers may use technology in different ways than researchers or developers may have intended. Technology use on farm is also driven by factors more complex than simply the profit-based motives assumed by those designing and selling the technology (Schmoldt 2001). Adaptation of technology during integration into farm management practice is an important process by which farmers find solutions to problems specific to their farm management system. On-farm shaping of technology highlights the need to understand real-world determinants of technology use on farms.

The on-farm shaping was highlighted by the farm management adaptation that case study farmers undertook to incorporate new precision dairy technology (section 2.3). Observation of these farmers suggested that high accuracy and reliability was more crucial in areas such as cow identification compared to others such as milk yield recording and cow activity recording. The findings of Mein et al. (2001) and Clarke and Hannah (2007) suggest that lower precision sensors would have negligible impact on achievement of farm management goals. In this chapter
the importance of accuracy and frequency are discussed via an investigation into
the design of precision dairy systems of ‘experienced users’ of PDF-ICT systems.

6.2.3 On-farm shaping of technology by case study farmers

The case study farmers provided insights into the adaptation of precision tools and
the precision concept in general. A key feature of their initial experiences with the
technology was a ‘bedding in’ period where accuracy was lower than expected.
This led to a process of management adaptation to account for the PDF-ICT
inaccuracy. The extent to which farmers expressed concern over accuracy
depended upon the risk profile associated with the intended use of data. Farmers
were also taking ‘precise’ data and applying it in ways which diluted its precision.
These issues are expanded upon below.

Do farmers want accurate or frequent data?

Overall PDF-ICT accuracy is highly dependent on accuracy of the EID component.
If the data derived from other sensors is to have relevance it first must be
attributed to the correct cow. As stated by Jago and Calder (2007), “without the
ability to identify the cow correctly, and her position in the shed, no other feature
would be of much use”.

All case study farmers had been using herd testing prior to PDF-ICT installation.
When making the decision to invest in milk meters they cited the need for more
frequent data in order to respond to changes in individual cow feed requirements.
While some farmers in the industry do use milk yields provided by herd testing to
determine in-bail grain feeding rates, case study farmers perceived monthly data to
be of insufficient frequency. Two factors were involved in this perception: firstly that
monthly data would not pick up the more subtle changes in feed requirements due
to variation in pasture on offer and climatic factors impacting on energy balance of
the cow; and secondly that due to natural daily variation in milk yield the monthly
data may not provide a true representation of a particular cows performance.

Farmers were operating within margins of acceptable accuracy that were
dependant on desired management outcomes and the concept of a risk profile
related to end use is discussed below. Their perceptions were also underpinned by the capability to directly judge the accuracy of a particular technology. For example EID inaccuracy can be visually recognised through falsely identified cows whereas inaccurate conductivity or cow activity readings are less obvious. The importance of EID accuracy to PDF-ICT systems, and for use in individual feeding, was expressed by Mr B:

‘We’re getting 98% of the cows … you milk 400 to 500 cows that’s 10 cows not getting fed. I said we put this system in because [NLIS eartag based system] was 95%, I said it’s got to be 100%.’ (Mr B, May 2006)

Milk meter accuracy was an important consideration in farmers’ purchase decisions, as highlighted by Mr D’s comment below explaining how perception of milk meter inaccuracy turned him away from a particular product. In respect to this comment it is also interesting to note that inaccuracy of PDF-ICT technology can be judged by a farmer’s perception as much as reality. Up to half of the five litres per cow daily variation referred to below may be due to natural variation (Mein et al. 2001).

‘I went in there and I looked at the milk data and if you look at it our individual graphs they are pretty consistent between night and morning milking, when you go in and look at the [product name] system with the [brand of milk meter] there is a five to six litre per day variation on individual cows … I printed out half a dozen reports on the guy’s system and over 10 days there was no consistency.’ (Mr D, May 2006)

Milk meter accuracy can be assessed by a calibration process but few farmers in the case studies or scoping study actively calibrated individual meters. Instead they were content to measure accuracy at a bulk level through comparison between total daily PDF-ICT derived milk yield and milk vat volume or milk tanker receipts. Overall farmers had a lower margin of acceptable error for EID accuracy in comparison to milk yield data, and a larger margin of acceptable error for the more abstract measurements such as conductivity and cow activity.
The impact of risk profile of end use
The margin of acceptable error for PDF-ICT accuracy reflected the risks associated with incorrect cow identification or an inaccurate reading. For example, automated drafting for artificial insemination and automated alerts identifying antibiotic-treated cows both rely on the EID system. The farming system risk associated with incorrect ID for a cow treated with antibiotics is far greater than in the drafting scenario due to financial penalties incurred when antibiotics are detected in milk collected by the processor. Two comments from Mr A exemplify the link between EID accuracy and the risk associated with end use. The first comment relates to the use of PDF-ICT for automated drafting, while the second relates to identification of cow position in the milking stalls. When assessed on a percentage basis both comments relate to similar accuracy (4 misreads per 300 cows milked represents over 98.5% accuracy) but his satisfaction with each scenario differs.

‘We’re rapt with that, like it’s not 100% yet but I reckon it would be 98 or 99% of what they reckon and it does catch a few more than what we want but that doesn’t bother me, a few extras. Like we have been doing a lot of drafting in the past five weeks with joining and I would only know of a couple of cows that it has missed, like it probably has missed some that I don’t know of.’ (Mr A, November 2005)

‘I was talking to a guy up the road the other day and he’s got the collars and he reckons that they milk 300 and they get 4 on average that don’t read which I was a little bit surprised with that … I personally would be a bit disappointed in that, so its made me a little bit more aware of watching the last cow in the last bail.’ (Mr A, August 2005)

A less immediate risk, but still potentially damaging to milk production over the short term, is the incorrect allocation of feed to individual cows. This is not only a concern because of risks of rumen health in cows being fed high rates of grain, but misallocation of feed also fundamentally undermines the concept of maximising production, and profitability, through use of concentrate feeds. Mr B summed this up with his thoughts around poor EID accuracy and the implications for feeding:
‘Well the NLIS tags work reasonably well, probably work 90% of the time. That means it’s not working 10% of the time that means 10% of your cows every single day aren’t being identified properly, which means they’re not being fed properly, so how much production are you missing out by that happening?’ (Mr B, August 2005)

The scoping study and case studies provided an indication of farmers’ acceptable margin for error with PDF-ICT components. However more focussed research was required to assess the relative importance of the factors involved in precision dairy systems, therefore a further study was designed to address this aspect and this is outlined in section 6.3.

**Accurate data for imprecise management**

An important factor in PDF-ICT investment involves matching the level of capitalisation to the end use goals. While some farmers in the case studies and scoping study were making use of the technology at a level matching the data quality and quantity, others had adopted management practices which effectively diluted the power of the data. Mr A averaged individual cow milk yield data for two groups. He then measured his day-to-day performance based on the total milk each group was producing. Mr E was collecting precise daily milk yields but using a flat grain feeding rate across the herd. In cases like these a milk meter with lower precision may have still enabled the farmers to achieve their goals.

There can also be a mismatch in precision of feeding to production regimes. Collection of accurate milk yield information and design of precisely proportioned feed allocation based on milk yield is worthless if the feed delivery system is inaccurate. Augers wear over time potentially altering the volume of feed delivered per auger revolution, and different batches of grain have different densities. These two factors highlight the need for regular calibration of the feed delivery system, which can be a simple process as outlined by Mr E:

‘Every time you change the grain, or get a new load of grain in, you’ve only got to push the button and put a bucket and catch what comes out of the
chute and then weigh it, and if it changes you’ve just got to re-enter the calibration, in the pit, not in here, you just enter the codes and it comes up with feed calibration and you say ok its dropping instead of 2kg its dropping 2.2kg, and that will automatically adjust it. In the new set up you’ve got accuracy, everything’s accurate, so you can be sure of how much is occurring, how much cows are getting and with the going to fully automated feeding it just gives you that extra accuracy and extra management ability.’ (Mr E, February 2007)

However, not all of the case study farmers regularly calibrated their feed delivery system. Mr A found his feeding system was delivering the wrong feed for a month only through noticing that he wasn’t refilling a main grain storage bin as much as he should have been. Mr D provided an example on his farm where the protein source had actually run out several days prior to it being noticed. Regular calibration would have uncovered these inaccuracies.

Milk meters provide data on individual cow milk production on a milk volume basis (litres). Most farmers interviewed in the scoping study and case studies based their feeding regimes directly on cow milk production in litres, usually in consultation with a nutritionist. Economics of feeding rates were determined through assessment of the marginal return from increased litres per cow for every kilo of grain added. However, as Gibb (2006) noted, the most appropriate method of estimating milk value is to use $/kg milk solids (MS) because almost all milk payment systems used in Australia are based on the formula ‘protein plus fat minus volume’. Therefore a more accurate feeding rate should be based on the extra MS produced per extra kilogram of supplement (ibid.). The fine tuning of supplement feeding based on production in litres provides another example of using accurate data to make precise management changes, which in reality are undermined by inaccurate application.

In some instances the most beneficial aspect of precision dairy systems can be associated with improved basic record keeping. Alerts indicating cows about to calve, cows due for pregnancy tests, and cows treated with antibiotics are all based on manually entered data. The value of this information hinges on accurate
data input in addition to accurate EID. Benefits arise from timelier decision-making and also greater ease of cow management at milking.

The examples provided in this section highlight that precision farming accuracy should have a wider farming system focus rather than just the ICT devices. The need for highly accurate devices is called into question when the subsequent use of the data effectively creates inaccurate management practices.

**Adaptation around technology performance**

Farmers in the scoping study and case studies adapted their management routines according to PDF-ICT system performance. Through this on-farm shaping of precision dairy systems, users were able to account for accuracy or reliability concerns. While some adaptation was minor, there were also cases where the adaptation was significant and brought into question the technology’s fit-to-task. Most importantly these instances, examples of which are outlined below, highlight the importance of on-farm adaptation to fit the PDF-ICT system with specific farm management. It is also an indication that PDF-ICT systems can not be viewed as ‘plug and play’ technology that can be used across all dairy management systems without associated adaptation by users.

Adaptation involved issues of risk management, trust, adjustment of margins for error, or substitution of practices. Most farmers interviewed maintained the use of tail paint or leg tags to identify cows which had been treated with antibiotics, even though they also used ICT-based alerts. The continued use of manual methods was viewed as a back-up for the ICT system, exhibiting a lack of trust in the EID accuracy. Similarly some farmers replaced the freeze-brands on their cows so they could be seen during milking, and/or slowed down the milking speed to facilitate cross-checking between EID and branding, both back-ups to cover EID inaccuracy.

Trust was an important component determining the extent to which case study farmers integrated PDF-ICT into their management. Building of trust was based upon perceived accuracy and reliability of the new system which took time to prove and was based on individual tolerances for error. An example of this was Mr A’s
continued use of the previous herd management software and his hardcopy diary for over 18 months after beginning to use the new ICT software. He used the triple-entry system in case the new system crashed and lost vital data. Mr B developed little trust in EID accuracy, and aspects of the software itself, which constrained his overall use of the PDF-ICT system. He did not use alert functions or enter data into the database as he saw it as a wasted effort if cows could not be identified correctly. Mr B provided an example of the impact of a high expectation for accuracy and reliability in respect to the level of trust in, and subsequent use of, precision dairy technology. Matching farmer expectations and tolerances around system performance is addressed in section 6.3.

Management adaptation related to issues of PDF-ICT accuracy and reliability also occurred in a more positive sense. Some farmers using pedometers for cow activity sensing trusted them to the extent that they no longer used any other method of oestrus detection. Additionally, many of those interviewed commented that the quality of milk yield data under a PDF-ICT system was superior to that provided through herd testing. Foreknowledge of potential issues also allowed farmers to account for it in their investment decision-making. For example Mr A heard about the potential for EID misreads prior to purchasing his system and adapted his investment to include functionality for manually fixing misreads during milking.

While on-farm adaptation of technology and management practice plays a vital role in ensuring the technological fit with individual farmer goals for precision dairying, the degree and form of the adaptation can provide an insight into the overall fitness of the technology. As described above, management practice adaptation can be both beneficial and detrimental to the precision dairying goals of increased control and efficiency. It might not be reasonable to expect the technology underpinning precision dairying to be 100 percent accurate and reliable but farmers should be aware of this in their purchase decision. Additionally, on-farm adaptation should not be required to ‘patch-up’ inadequate systems. Such measures, for example rebranding cows and slowing platform speeds to detect misread cows, represent lost efficiencies and undermine the fundamental reason for adoption of precision dairy practice.
6.2.4 Retailer representation of precision dairy systems

A key factor in the design of precision dairy systems is the interaction between retailers and farmers in the pre-purchase process. The relationship between farmer and salesperson was discussed in Chapter 5, and the importance of this stage in setting PDF-ICT expectations was identified. This study was primarily focussed on providing a farmer-based perspective of precision dairying. However, in order to gain an insight into how retailers represent the accuracy and learning challenges associated with their PDF-ICT products to potential users, a qualitative review of promotional material was conducted. The goal of this review was to identify information that might be influencing initial farmer expectations around PDF-ICT rather than offer a comprehensive analysis of marketing strategies. Observations and discussion from the review are provided in Box 6.1.
Box 6.1: Promotion of PDF-ICT products

How do retailers promote their PDF-ICT products?

Introduction:
A qualitative review was conducted to investigate how performance expectations were built in promotional material of the three different PDF-ICT products* used in the case studies. The desk-top study was aimed at viewing the technology from the perspective of a farmer potentially investing in PDF-ICT. Brochures and Internet-based material were reviewed for the three products in respect to references made concerning accuracy, reliability, potential on-farm adaptation, and the learning effort associated with adoption of PDF-ICT. This review was aimed at providing an indication of the impressions engendered by retailers, rather than a comprehensive analysis.

Observations:
The potential benefits for PDF-ICT involved increased profitability through increased efficiency, improved control, and savings in time spent on herd management tasks. There was a focus on making the ‘right decisions at the right time’ and the ability to have ‘total control’ through access to more information.

Technology accuracy was referred to with phrases such as ‘timely and correct information’, ‘precise feeding’, ‘always correct’, ‘reliable’, ‘perfect management in the milking parlour’, and ‘measures exact milk quantity’. However, references to accuracy almost invariably related to milk meter performance and no such claims were observed which related to EID accuracy.

In respect to the learning associated with PDF-ICT use, there was a focus on the technology being ‘easy-to-use’ or ‘user friendly’. Little mention was made of the new learning required, although one retailer did suggest learning to use their software would take ‘a maximum of one week’ to learn to use the ‘entire’ system.

Promotional documents were technology-focussed and the role of the farmer in the process was minimised. They gave the impression that the technology would take care of everything, with one retailer stating that their system ‘keeps track of each animal and provides exactly the right quantity and type of concentrate to each individual’.

Discussion:
While it is understandable that retailers positively promote their products, the results from this small review identified a highly technological focus in promotion, to the point where farmer involvement in precision dairy systems seemed minimal. It provided an impression that the technology was simply ‘plug and play’ with little adaptation or learning required. The documents also provided an impression that the accuracy of PDF-ICT systems was such that they could be relied upon almost completely. Retailers may not be expected to outline the potential areas of inaccuracy in their systems, but they should temper such promotion with more specific and honest assessments via one-on-one discussions in the pre-purchase process.

* Products have not been specifically named due to commercial sensitivity

The experiences of case study farmers underline the importance of acknowledging different perspectives of the role and capability of ICT. Mr B, Mr E, and Mr and Mrs F all had higher expectations of EID accuracy than was initially delivered. Where a retailer may view 98 percent EID accuracy as acceptable, a farmer sees the
accuracy in terms of the 8 cows in a 400 cow herd which could be misidentified each milking. Lack of confidence in the PDF-ICT system can manifest in an incomplete integration of the technology into management practice. Comments below provided by case study farmers highlight the potential differences between expectations for a PDF-ICT system and actual on-farm performance:

‘From what we were told we would be able to do to what we can actually do didn’t match up basically so that what we were told we could expect to be able to do with the software is completely different to what we can do ... initially what we were sold was that the program … could import [herd test results] into the system, and we could export data on cows out into another herd management software and we can’t do either.’ (Mr E, February 2007)

‘If you listen to [the retailer] it’s going to be absolutely perfect, but then talking to a couple of other farmers before we signed up for them they have the odd transponder that breaks.’ (Mr B, August 2005)

‘They told us that the system would detect cows that kicked their cups off by low milk yield, but [in reality] if they consistently kicked their cups off they have a low average milk yield therefore they go out unmilked.’ (Mr D, November 2005)

Weick (1990) stated that the perception of an individual toward introduction of technology is crucial to their eventual adoption of the technology. Griffith and Northcraft (1996) identified the paradox of positive value, where a new technology is portrayed in a positive light, with benefits quoted without mention of potential negative features. Consequently, when a negative experience occurs the user can be unprepared to deal with it and the technology is more likely to be rejected as a result. However, pre-knowledge of potential weaknesses of the technology can also be a bane according to Griffith and Northcraft (1996). Their paradox of negative experience suggests that experience with negative aspects of a new technology impact on a user’s perception of the technology’s applicability and merit. Such negative perceptions can be overcome through a gradual introduction of technology (Murrell & Sprinkle 1993).
Retailers of dairy ICT appear to promote their products in a highly positive manner emphasising efficiency benefits and the ‘cutting-edge’ nature of their technology (see Box 6.1). Neale and Chapman (2007, p.57) found “serious discrepancies between what the salesperson claims, what the farmer expects, and the unit’s capability” in the pre-purchase phase of GPS-based precision technologies in Australia’s arable sector. They highlight the need to match expectations to reality, and to have defined purchase goals. If one-on-one pre-purchase discussions between farmers and salespeople focus only on positive value then farmer expectations may be set at a level not achievable with the new system. If, as suggested by the paradox of positive value, farmers have an unexpected negative experience they may be more disaffected than if they were briefed on potential issues, as seen in Mr B’s experience in Chapter 4. As a result Mr B was reluctant to trust the system for use in his management practice. Mr D also quoted major unexpected costs his business incurred during the first year of ICT use.

It is important that, in the pre-purchase phase, the positive and negative experiences of PDF-ICT uptake are addressed. Retailers need not underrate the quality of their product, but the discussion should include additional factors surrounding ICT implementation. These factors involve what it will take to achieve the stated level of performance and benefits including the farm management adaptation required, possible downtime during the ‘bedding-in’ period, and any risks to the business associated with implementation. In the next section the results of a study into the perceived importance of features of precision dairy systems are presented and discussed, in respect to the issues highlighted above.
6.3 Farmer expectations for precision dairy systems

6.3.1 Introduction

The critique in section 6.2 focussed on the underpinning features of the precision dairy concept: data collection at a scale which facilitates greater management control over variable farm factors. The idea of appropriate scale is important because it emphasises that not all data needs to be 100 percent accurate. Highly accurate technology often comes at a cost to farmers, and with a finite budget for capital expenditure opportunities for wider investment can be lost.

Limited resources of time and money are important factors determining PDF-ICT investment. In a situation of limited resources, farmers are forced to make trade-offs between different component technology, along with trade-offs between time spent learning to use ICT and time spent doing other farm tasks. An exploratory study was conducted to investigate the decision process farmers use as they construct a precision dairy system. The use of PDF-ICT for individual cow feed allocation was used as the example for experienced precision farmers to reflect upon their preferences in respect to data frequency, data accuracy, and learning effort. Conjoint analysis was used to examine the trade-offs farmers would make, thereby assessing their expectations around specific aspects of precision dairy systems. This method was also used with a view to testing its effectiveness as a tool for PDF-ICT retailers to assess farmer expectations and tolerances around system performance.

6.3.2 Research questions

The study was focussed around three main research questions:

1. What trade-offs do farmers make in the development of their precision dairy systems when time and money are limited?

2. How important are accuracy and frequency of data when making feed allocation decisions?

3. What trade-offs will users make when faced with high learning requirements in the construction of their precision dairy system?
These questions resulted from case study findings in Chapter 5, and from the discussion presented in section 6.2.

6.3.3 Method

Using conjoint analysis to elicit responses

Conjoint analysis (CA) is a technique that requires respondents to make trade-offs between several alternative scenarios. The approach involves asking respondents to rate products with alternative levels of key characteristics. Johnson (1974, in Hurlimann & McKay 2007) stated that ‘the CA technique is based on the assumption that complex decisions are not based on a single factor or criteria but on several factors considered jointly’. According to Horst et al. (1996, p.3) CA involves two basic assumptions: ‘ (1) a product can be described according to levels of a set of attributes, and (2) the consumer’s overall judgement with respect to that product is based on these attribute levels’. In this study PDF-ICT was considered to be the ‘product’, and the assumptions around specific attributes were informed by the scoping study and case studies.

Conjoint analysis is generally used to quantitatively survey large groups of people with the aim of providing statistically significant answers to a research question. Van Asseldonk et al. (1998) used conjoint analysis to elicit expert opinions on the detection characteristics of IT-based tools for oestrus and mastitis identification. Horst et al. (1996) also used the technique to determine risk factors for contagious animal diseases. However, in this study the method was used as a tool to focus participants on the topic and to elicit qualitative responses regarding the trade-offs they made during the conjoint survey. In this way the reasons behind their decisions were captured and discussed.

In the interviews, participants were presented with three scenarios based around the premise that they were investigating the purchase of a new PDF-ICT system. The first scenario involved ranking PDF-ICT systems which differed in their milk meter accuracy, EID accuracy, and data collection frequency. The second scenario investigated the impact of learning load, by requiring participants to rank PDF-ICT systems which differed in their ease of learning, time to learn, and cost of learning. The third scenario combined the two previous exercises and required
participants to consider the impact of increased learning load on their technology investment priorities. The specific design of these scenarios is outlined below.

Respondents were asked to view each scenario as a separate potential PDF-ICT ‘product’, each with a varied mix of ‘attributes’ broken down into a number of ‘levels’ (see below). They were then asked to rank the scenarios from most to least preferred and then discuss the reason behind their choices. Interviews with participants lasted for between 30 to 60 minutes and were recorded for subsequent analysis. Background information was collected for each participant, including farm characteristics, demographic data, and specific features of their current PDF-ICT system.

**Pilot study**
The method was tested in a pilot study involving two dairy farm managers and two senior dairy research scientists. Key learnings from the pilot study involved the trade-off scenario procedure, the use of diagrams, and specific weighting of factors. The learning effort trade-off exercise was originally designed with two trade-off exercises, one for the most difficult technology scenario choice and the other for the easiest scenario choice. This resulted in pilot study participants being asked to run through the trade-off exercise between two scenarios that were both undesirable and therefore the exercise was nonsensical. The scenario cards used in the pilot study also had diagrams on the reverse side depicting each factor; these were removed as it was found participants understood the levels without the help of visual aids. Another adaptation resulting from the pilot study was the need to exaggerate some of the levels in order to create a larger difference between the options, for example the cost of learning was raised from $500 to $1000, and time to learn was changed to ‘3 months’ instead of the original ‘40 hours’. Aside from these changes the approach was deemed to achieve its aim of stimulating discussion around the topic.

**Participant selection**
The interviews were aimed at eliciting responses from dairy farmers who had experienced the learning challenges associated with implementing PDF-ICT, and who also had experience of using milk yield information for individual feeding.
Potential participants were therefore required to have over 2 years experience using daily milk yield information to make feed allocation decisions. A snowball sampling method was used (Bryman 2001), with initial participant names drawn from personal contacts of the researcher. Interviews were conducted until there was repetition of major themes, known as ‘saturation sampling’ (Bryman 2001). The interviews were exploratory in nature and were not designed to provide statistically significant results.

**Conjoint exercise one: Accuracy and frequency of data**

The first exercise was designed to investigate the importance of data accuracy versus data frequency. Analysis of the case study findings determined that the accuracy attributes that farmers valued most highly were electronic identification (EID) accuracy, and milk meter accuracy. The third attribute was data frequency. For each attribute a range of levels was generated, as listed below (see Table 6.1).

**Attribute 1 - Milk meter accuracy**
Definition: The relative accuracy of milk meter data collected
- High (recorded data will be within 1% of actual milk yield, as with highly accurate milk meters)
- Medium (recorded data will be within 3% of actual milk yield, as with lower specification milk meters)
- Low (recorded data will be within 10% of actual milk yield, included as an example of uncalibrated milk meters)

**Attribute 2 - Electronic identification (EID) accuracy**
Definition: The relative accuracy of the electronic identification system
- High (all cows identified correctly all the time)
- Medium (98% accuracy or 2 misreads for every 100 cows, represents accuracy experienced by many farmers in the scoping and case studies)
- Low (90% accuracy or 10 misreads for every 100 cows, very poorly operating EID system)

**Attribute 3 - Data frequency**
Definition: The frequency with which milk yield data is collected
- Daily (milk yield data collected each milking, as in PDF-ICT systems)
- Monthly (milk yield data collected once per month, as in herd testing)
Table 6.1: Summary of the attributes and levels used to create conjoint exercise one

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk meter accuracy</td>
<td>High (+/- 1%)</td>
</tr>
<tr>
<td>EID accuracy</td>
<td>High (100%)</td>
</tr>
<tr>
<td>Frequency</td>
<td>Daily</td>
</tr>
</tbody>
</table>

This structure resulted in 18 possible combinations, of which many were nonsensical and therefore discarded. The ‘ideal system’ of high accuracy factors and daily frequency was also omitted, because with no factor included for cost this card would have always been ranked top. Six scenarios were chosen (Table 6.2, Appendix 2) to focus discussion around ‘products’ that farmers could relate to.

Table 6.2: Combination of levels in each of the six scenarios (A-F) used in exercise one

<table>
<thead>
<tr>
<th>Levels within Attributes</th>
<th>Concept</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk meter accuracy</td>
<td>EID accuracy</td>
<td>Data frequency</td>
</tr>
<tr>
<td>A</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>B</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>C</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>D</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>E</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>F</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

* Entry level system does not include in-line milk meters, see Chapter 2.

Participants were presented with the six scenarios as a series of separate cards, enabling them to manipulate the cards into order on a table during the interview. They were then asked to indicate the two scenarios that were hardest to choose between, for use in conjoint exercise three. The explanation of the exercise provided to participants is shown in Box 6.2.
**Box 6.2: Conjoint exercise one as explained to participants**

**Background**
Imagine you have bought a new farm and are purchasing a computerised herd management system based around EID and milk meters with the aim of improving feed efficiency.

Six options for the new system are presented on separate cards, each containing a different combination of data accuracy, EID accuracy, and frequency. Each option involves some trade-off between the three attributes. This exercise is focussed on your ranking of these six options, rather than looking just at your preferred option.

**Exercise 1**
Drawing on your experience with your current herd management system your task is to rank the presented scenarios in order from the one that you would most prefer through to the one you least prefer.

I will then ask you some questions about your ranking.

**Exercise 1a**
1a) Which two adjoining scenarios in the previous exercise were most difficult to choose between when ranking?

---

**Conjoint exercise two: Impact of learning effort**
The second exercise was aimed at assessing the impact of different attributes associated with the ‘learning effort’ of a PDF-ICT system. Findings from the scoping and case study highlighted the new learning required with PDF-ICT systems. Users will perceive the learning challenge differently depending on issues such as their experience and confidence with ICT. Three attributes were chosen to cover learning effort: ease of learning, time to learn, and the cost of support (Table 6.3).

**Attribute 1 - Ease of learning**
Definition: How complex a person finds achieving basic competency in PDF-ICT system use. Ease of learning will differ from person to person depending on their computer skills and learning style, and for this study two levels were chosen.
- Easy to learn (involves skills the user already had with computers with a small requirement to spend some time relearning – likened to learning to use a new phone)
- Complex to learn (a significant amount of new skills are required - likened learning to use a personal digital assistant (PDA))

**Attribute 2 - Time to learn**
Definition: The duration required to learn PDF-ICT features so that the user can competently engage with the system for day-to-day tasks. The two levels were:
- 1 month (after approximately one month of learning and using the system, users can find basic data and create basic reports)
- 3 months (after approximately three months of learning and using the system, users can find basic data and create basic reports)

**Attribute 3 - Cost of support**
Definition: Whether a PDF-ICT user needs to pay for learning support in order to achieve competency in the use of PDF-ICT. The two levels were:
- No cost (the cost of training is factored into the PDF-ICT sales contract)
- $1000 ($1000 would be required in order to pay a trainer to support the learning process, this is not included in the sales contract)

**Table 6.3:** Summary of the attributes and levels used to create conjoint exercise two

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of learning</td>
<td>Easy to learn</td>
</tr>
<tr>
<td>Time to learn</td>
<td>1 month</td>
</tr>
<tr>
<td>Cost of support</td>
<td>No cost</td>
</tr>
</tbody>
</table>

The concepts used in exercise two were more abstract than those in exercise one, therefore the number of levels per attribute was simplified to two (Table 6.3). As a consequence there were a total of 8 possible combinations, all of which were used in the exercise (Table 6.4, Appendix 3). Some of the scenarios appeared to have contradicting levels, for example scenario ‘C’ which represented a situation where the PDF-ICT system was easy to use yet took three months to learn and required
$1000 worth of additional support. These scenarios were included in the exercise in order to see how participants made sense of such seemingly contradictory levels.

**Table 6.4:** Combination of levels in the eight scenarios (A-H) used in exercise two

<table>
<thead>
<tr>
<th>Attributes and levels</th>
<th>Ease of learning</th>
<th>Time to learn</th>
<th>Cost of support</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Complex</td>
<td>1 month</td>
<td>No cost</td>
</tr>
<tr>
<td>B</td>
<td>Easy</td>
<td>1 month</td>
<td>No cost</td>
</tr>
<tr>
<td>C</td>
<td>Easy</td>
<td>3 months</td>
<td>$1000</td>
</tr>
<tr>
<td>D</td>
<td>Complex</td>
<td>3 months</td>
<td>$1000</td>
</tr>
<tr>
<td>E</td>
<td>Complex</td>
<td>3 months</td>
<td>No cost</td>
</tr>
<tr>
<td>F</td>
<td>Easy</td>
<td>1 month</td>
<td>$1000</td>
</tr>
<tr>
<td>G</td>
<td>Complex</td>
<td>1 month</td>
<td>$1000</td>
</tr>
<tr>
<td>H</td>
<td>Easy</td>
<td>3 months</td>
<td>No cost</td>
</tr>
</tbody>
</table>

Participants were presented with the eight scenarios as a series of separate cards, and, as with exercise one, they were asked to rank the cards from most preferred to least preferred. The reasons behind their ranking were used to stimulate discussion on the relative importance of the learning attributes. The explanation of the exercise provided to participants is shown in Box 6.3.

**Box 6.3:** Conjoint exercise two as explained to participants

**Background**
You have purchased a new system which requires a certain level of learning effort to enable you to become competent in using the system.

Eight options are presented on separate cards, each containing a different combination of ‘ease of learning’, ‘time to learn’, and ‘cost’. As before, this exercise is focused on your ranking of these eight options, rather than looking just at your preferred option.

**Exercise 2**
Drawing on your experience with your current herd management system your task is to rank the presented scenarios in order from the learning effort you would most prefer through to the one you least prefer.

I will then ask you some questions about your ranking.

**Conjoint exercise three: Learning effort trade-off**
As a final exercise, a trade-off scenario was used to ascertain the impact of increased learning effort on the design of farmer’s precision dairying systems (Box
The two scenarios identified by participants in exercise one as difficult to choose between were placed in front of the participant in the order they had previously ranked them. The most preferred learning effort scenario from exercise two was then attached to the less preferred of the two exercise one scenarios. This simulated a situation were the less-preferred technology attributes required the least learning effort. The more highly preferred technology option was then moved progressively up the learning effort scale. At each step up the scale the participant was asked if he/she would swap his/her ranking of the exercise one scenarios. If at any point they decided that the additional learning effort of their more preferred card was sufficient to alter their previous ranking, the trade-off exercise was stopped and the decision point noted and discussed.

**Box 6.4: Conjoint exercise three as explained to participants**

<table>
<thead>
<tr>
<th>Exercise 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>I will present you with a learning requirement associated with the top ranked scenario in 1A to see if it would make you change your previous ranking. If not, I will present increasingly difficult learning requirements in an attempt to produce a change in ranking.</td>
</tr>
</tbody>
</table>

**Data analysis**

Results from the conjoint exercise were collated to provide an overall indication of participant’s preferences, rather than draw any statistical conclusions. A brief summary of these quantitative results is provided below. Primary findings were drawn from the subsequent discussion around why participants ranked the scenarios in a certain order. NVivo™ qualitative data management software was used for the thematic analysis and creation of memos from participant comments (see Chapter 2). Digital recordings of interviews were used to confirm field notes.
6.3.4 Results

Participant profiles
Nine farmers participated in the study, and their farm size ranged from 160ha to 1000ha with herd sizes from 240 cows to 1300 cows. Farm business structure included family farm, partnerships, and companies. All of the participants were male, with three aged 25-35, four aged 36-45, one under 25 and the other 56-65. Most participants went straight from high school into farming; three started undergraduate degrees with only one graduating. Use of nutrition consultants was prevalent due to all participants using individual feeding based on milk production. Participants are referred to by pseudonym's to provide anonymity.

In terms of PDF-ICT components, seven of those interviewed had collar-based EID, with one NLIS EID and one bolus-based. All had milk meters and automatic cup removers (ACRs), while six had conductivity sensors, and five had activity sensors. All of the systems cost over $100,000 to install and some had been used for over seven years.

Conjoint exercise one
Summary of scenario rankings
In exercise one, the most preferred card chosen by all but one of participants was ‘D’ (medium milk meter accuracy, high EID accuracy, daily frequency) (Table 6.5). The second most preferred scenarios were ‘C’ (3) and ‘F’ (4), which both provided daily data but had high/low and low/high milk meter and EID accuracy respectively. The least preferred cards were ‘E’ (high milk meter accuracy, medium EID accuracy, and monthly frequency) chosen by five participants, and ‘B’ (low milk meter accuracy, low EID accuracy, daily frequency) chosen by three participants.
Table 6.5: Participant ranking of six scenarios used in conjoint exercise one

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Most</th>
<th>Ranked position (most to least preferred)</th>
<th>Least</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>1 2 2 4 0</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>0 0 4 2 3</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>1 3 0 2 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>8 1 0 0 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>0 0 2 2 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>0 4 2 1 1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In Table 6.6 the rankings are presented as a percentage occurrence of each level by ranked position. Because each factor occurred between one to four times in the six scenarios, the results were converted into a percentage of total occurrence. Results from the ‘1 to 2’ ranking position data (Table 6.6) indicate that the most important factor for participants was high EID accuracy (52%), closely followed by access to daily milk yield data (47%). The least preferred attributes (in the ‘5 to 6’ ranking position) were medium EID accuracy (56%) and monthly data recording (50%). Medium milk meter accuracy was not a deterrent to participants, with the one scenario including this factor always ranked in the top two.

Table 6.6: Occurrence of levels by ranked position (percentage of total occurrence)

<table>
<thead>
<tr>
<th>Ranking position*</th>
<th>Milk meter accuracy</th>
<th>EID accuracy</th>
<th>Data frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Med</td>
<td>Low</td>
</tr>
<tr>
<td>1 to 2</td>
<td>19</td>
<td>100</td>
<td>22</td>
</tr>
<tr>
<td>3 to 4</td>
<td>41</td>
<td>0</td>
<td>39</td>
</tr>
<tr>
<td>5 to 6</td>
<td>41</td>
<td>0</td>
<td>39</td>
</tr>
<tr>
<td>n</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

*where 1 represents most preferred by participants and 6 represents least preferred
‘n’ refers to the number of times this factor occurred across the six scenarios

Participant justification for choices

The main themes arising from conjoint exercise one are summarised briefly below and are revisited in section 6.4 from the perspective of ‘people in technologies’.
When forced to make a trade-off, PDF-ICT users were prepared to sacrifice accuracy in milk yield data for high EID accuracy. EID accuracy played an important role in engendering confidence in the collected data. ‘The most frustrating thing is the accuracy of the EID, because you can have an accurate measurement of milk, but if it’s putting it to the wrong cow, or not at all, then that’s not going to get you anywhere at all.’ (Conjoint A, 2007)

Lower EID accuracy was perceived as surmountable by farmers, but led to greater use of risk management procedures and also reduced overall use of PDF-ICT for management. Some of those interviewed were confident that they could manually correct for EID inaccuracy, but did not have faith that their staff could be relied upon to do the same. Farmers adapted their management to compensate for inaccurate EID, usually by ‘reshuffling’ cow EID into the correct bail. In cases where the PDF-ICT system made this shuffling process easy farmers were confident they could cover for 3% inaccuracy. Some systems do not have this real-time EID shuffling functionality which consequently limits the user’s ability to adapt around inaccuracy.

As described earlier in this chapter the importance of EID accuracy relates to the risk associated with its end use. When using the system for feeding to production, daily recording is paramount and according to one participant EID accuracy can be traded-off because a cow “can miss [being fed correctly] one milking, it won’t be do or die.”

Data frequency was paramount when used to determine individual feeding rates. Individual cow variability, and environmental factors which might influence large daily milk yield fluctuations, were considered by participants to lead to misrepresentative results when data are collected monthly. ‘Because I know my system’s really accurate I’ve got cows on low feed and cows on very high feed, if I was only doing a monthly [milk yield measurement] I’d probably bring the range up, narrow the range a bit, so
that a cow that gets a bad test her feed won’t be so bad.’ (Conjoint C, 2007)

Lower milk yield accuracy could be accommodated by using rolling averages, with 7-day averages commonly used amongst participants. Variation in accuracy could also be accounted for by setting alerts based on milk yield changes over two days rather than one. There was a limit to acceptable milk meter accuracy, with 10% variation perceived to be inadequate:

“You’ve got to start wondering, although you’re getting the cows right, 10% [milk meter inaccuracy] is a long way to be off. You’d definitely look at why are we paying big money for 10% inaccuracy.’ (Conjoint E, 2007)

This indicates a threshold for each component where the suitability of the whole system could be brought into question. When constructing a precision dairy system the participants in this study were prepared to trade-off certain features of a PDF-ICT in order to achieve desired functionality in other components, however there was a limit to their ability to make trade-offs.

Conjoint exercise two

Summary of scenario rankings
In exercise two, eight participants listed scenario ‘B’ (easy to learn, 1 month, no cost) as most preferred (Table 6.7). Scenario ‘F’ (easy to learn, 1 month, $1000) was the second most preferred. The least preferred scenario by all participants was ‘D’ (complex to learn, 3 months, $1000), with ‘E’ (complex, 3 months, no cost) second least preferred. The ranking of ‘B’ and ‘D’ provide no surprise as they represent the clear minimum and maximum learning effort respectively. The ranking of ‘F’ and ‘D’ highlighted the importance participants placed on ease of learning and time to learn, and the relative lack of importance of cost of training.
Table 6.7: Participant ranking of eight scenarios used in conjoint exercise two

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Ranked position (most to least preferred)</th>
<th>Most</th>
<th>2</th>
<th>0</th>
<th>1</th>
<th>3</th>
<th>2</th>
<th>0</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>0</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

As in exercise one, the scenario rankings from exercise two were broken into individual levels and converted to represent a percentage of total occurrence (Table 6.8). In scenarios ranked 1 or 2 the levels ‘easy to learn’, ‘1 month’ and ‘no cost’ were all equally prevalent (42%). In terms of the least preferred levels, participants were most sensitive to ‘complex’ learning (47%), followed by ‘3 months’ (42%), and ‘$1000’ cost (36%). The results indicate that participants were prepared to trade-off low cost to achieve easier and less time-consuming learning.

Table 6.8: Relative occurrence of levels by ranked position, as a percentage of total occurrence

<table>
<thead>
<tr>
<th>Ranking position*</th>
<th>Ease of learning</th>
<th>Time to learn</th>
<th>Cost of training</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Easy</td>
<td>Complex</td>
<td>1 month</td>
</tr>
<tr>
<td>1 to 2</td>
<td>42</td>
<td>8</td>
<td>42</td>
</tr>
<tr>
<td>3 to 4</td>
<td>39</td>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td>5 to 6</td>
<td>16</td>
<td>34</td>
<td>28</td>
</tr>
<tr>
<td>7 to 8</td>
<td>3</td>
<td>47</td>
<td>8</td>
</tr>
<tr>
<td>n</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

*where 1 represents most preferred by participants and 8 represents least preferred
‘n’ refers to the number of times this factor occurred across the eight scenarios

Participant justification for choices
The main themes discussed during conjoint exercise two are outlined in this section and are further explored in section 6.4 in the context of people in technologies.
The ranking of learning effort proved a difficult cognitive challenge for participants but the discussion surrounding their ranking helped to expand on the decision processes. For most participants the ease of learning and time to learn were fundamental attributes. Easy to learn PDF-ICT was preferable to farmers not just for their own learning, but for that of their staff. While staff were generally not expected to be heavily involved with in-depth data analysis, they needed to acquire basic skills to carry out milking activities.

‘Staff are employed to milk cows, they are not employed, dollar-wise, to learn the system backwards, they need to know how to get around the system, they don’t need to know the fine-tuning side of it.’ (Conjoint G, 2007)

Therefore, while the primary users of PDF-ICT generally expressed confidence in their own ability to learn complex systems, staff skill with the technology was a key determinant in their construction of precision dairy systems. PDF-ICT complexity in itself was viewed differently by respondents. On one side, high learning complexity denoted a more desirable system due to powerful and flexible capability. Alternatively, complex systems were viewed by others as signalling potential difficulties for staff learning and utilisation, and these users preferred a more basic and intuitive interface.

A shorter learning period was vital for users because ‘time is money’ and the longer it takes to reach competency the greater the lost opportunities. Consequently, farmers were prepared to pay to reduce learning time as they perceived the benefits of getting up to speed with use of PDF-ICT would outweigh the additional cost.

‘$1000 probably not a lot to pay when you’ve already spent $100k, and when you’ve got staff a minimal time to learn is preferable. If you learn quicker it is probably going to pay for itself.’ (Conjoint E, 2007)

Willingness to pay reflected an individual’s management mindset and there were other farmers who believed that training should be included free as they had
already invested heavily in the ICT system. A possibility exists for basic training to be included in the purchase contract, with additional charges for training around advanced features.

The farmers interviewed were notable in their optimistic attitude toward learning, something not present in all precision dairy farmers encountered during the course of this study. Most conjoint participants were determined to achieve a rapid return on their investment and a fast learning curve was vital, as one farmer stated “three months [learning] is like pulling a tooth out”. The learning effort that they had experienced to achieve competency in basic PDF-ICT use was viewed as minimal. However, more advanced use required an ‘understanding of your business’ with an initial phase of building confidence with the technology and a commitment to sit down and learn. One participant commented that PDF-ICT was sold to him with a technology focus rather than with an emphasis on specific benefits to his farm system.

**Conjoint exercise three**

*Summary*

In this exercise most participants (seven out of nine) maintained their original ranking of the two cards regardless of increased learning effort associated with the top ranked card. Of the two who did alter their ranking, one found the learning disparity in learning effort too great after four cards had been placed, and the other after five cards had been placed.

*Participant justification for choices*

Through this exercise participants made it clear that it was the material technology that was most important to them, and that learning effort was a secondary consideration. Increased cost of learning and increased time to learn generally did not change system preferences. The accuracy and reliability of the PDF-ICT system was more important to users than a high associated learning requirement.

The outcome of this exercise suggests that farmers are prepared to put time and effort into learning, in order to ensure they obtain a system suitable for their management needs. This is contrary to the observations in the six farm case
studies where many farmers had difficulty finding the time or enthusiasm to focus on PDF-ICT related learning. One explanation for this is that the learning effort scenarios in the conjoint exercise were not sufficiently imposing or that participants found the learning effort concept cognitively difficult. An alternative explanation is that as experienced users the nine study participants had gained confidence in the use of PDF-ICT and were therefore more open to an increased learning burden.

**Reflection on conjoint method**

The method used in this section was designed to focus participants around the trade-off concept and to elicit responses around their thought processes when constructing precision dairy systems. In general the conjoint technique achieved its purpose however reflection on its use helps frame the relevance of the results while providing guidance for similar research, and use of the tool, in the future.

Participants connected easily with conjoint exercise one, but on reflection the difference between levels within attributes could have been exaggerated to force greater thought in the trade-off process. Conjoint exercise two and three proved more difficult for participants to connect with as they dealt with more abstract concepts associated with learning effort, for example different people will perceive ‘easy to learn’ and ‘complex to learn’ differently. There was also confusion about certain factor combinations, for example a scenario that included ‘easy to learn’ and ‘3 months’ to learn appeared incongruous to some participants. Design of the attributes was aimed at providing tangible concepts that farmers could engage with however within the scenarios there was opportunity for individual interpretation.

This study highlights the potential applicability of conjoint analysis as a tool for retailers during the pre-purchase process. While the study participants struggled cognitively with some aspects of the method they were still able to use the exercise to clearly express a preference for rapid, easy-to-learn systems. With further development of the specific attributes, and adjusting the levels within attributes, a quick assessment based around a conjoint analysis approach could determine features of the devices and learning package which were important to potential clients.
6.4 Implications for construction of precision dairy systems

The research outlined in this chapter, and throughout the study, has helped identify considerations for construction of Australian precision dairy systems. The PDF concept entails an inherent complexity, not just due to the challenge of incorporating ICT and data into farm management, but also the variety of technology options and continuum of their application in farm management. A major determinant of individual farmers’ construction of precision dairy systems is the extent to which they are constrained by time and financial resources. In the discussion below, the role of people in technological systems is emphasised as a driver of the construction process, especially with respect to adaptation, information requirements, perceptions of learning effort, and tolerances for risk.

6.4.1 Processes of management adaptation

The conjoint study specifically highlighted the considerable ability that farmers exhibited in adapting their management around precision technologies, and in particular around glitches or mismatches. The processes involved with on-farm management adaptation have been largely overlooked in precision farming development yet it is a crucial step determining the extent of use and benefit derived from the technology. The research in this chapter builds on the theme of the role of farmers in filling a gap between performance of PDF-ICT and the required outcomes for management control.

It is important to consider the extent to which farmers should be expected to adapt PDF-ICT to suit their particular enterprise. In the cases of farmers interviewed for this study a high level of management adaptation was indicative of dysfunctional hardware or software which farmers had to account for in their practices. Farmers perceive PDF-ICT technology to be ready to plug-and-play, a perception partly driven by retailer promotion. Given the complexity and individuality of Australian dairy systems, in addition to the technological complexity of PDF-ICT systems, it is unreasonable to assume such ease of fit. Batte and Arnhold (2003, p.139) identified a similar issue for precision cropping farmers in the USA, stating:
‘Of importance to researchers is the observation that many of these highly capable farmers expressed frustration with the hardware, software and procedures of the system. It is clear that this is not a turn-key technology.’

Therefore the need for management adaptation has to be explicitly built in to the construction of precision dairy systems, rather than falsely assuming that no post-installation adaptation is required. In the future, developers and retailers should place more emphasis on the learning processes behind adaptation, in order to make adaptation a more efficient practice. To pave the way there needs to be a focus on the determinants of effective learning, such as the core competencies identified through the case study research. Prior to a farmer purchasing the technology, a brief individual assessment could be performed, targeted at identifying strengths and weaknesses for learning and adaptation and assessing tolerances for error. With this information, retailers and their farmer clients can construct a plan for learning and management adaptation during the early learning phase of precision system development.

6.4.2 Where are data and devices needed?

The results of this study highlight that the accuracy and precision required from precision farming devices is dependant on the end use of data. It is important to recognise where precise and accurate data are required, and where lower quality but high frequency data is acceptable to users. Precision dairying is set for expanded use in Australia and the immediate future holds many possibilities for new precision dairying tools. Advanced sensors for measurement of milk components, somatic cells, and pasture mass are currently entering the market, while other tools such as rumen sensors and automated cow condition scoring are late in the development cycle. However, EID is the backbone of herd management systems and dairy farmers interviewed during this study accentuated the importance of accurate cow identification. First and foremost cows have to be correctly identified if peripheral data are to be used effectively. Therefore the precision of other PDF-ICT sensors is irrelevant if the EID system cannot accurately attribute the collected data to the right cow. In constructing their precision dairy systems farmers are consequently prepared to sacrifice milk yield
accuracy so long as data are collected frequently and matched to the correct animal. This suggests that reliable, lower accuracy sensors could still provide data that is meaningful to a farmer with the benefit of reduced capital cost. More research is warranted on this aspect to ascertain in which decision-making areas high accuracy data is required and where it is not. van Asseldonk (1999b) and Huirne et al. (1997) investigated the areas where data are required on dairy farms, but did not take into account factors such as data quality and frequency.

6.4.3 Information and the climate of uncertainty

In designing precision dairy systems, the reality of farming within an environment of uncertainty should be acknowledged. The usefulness of accurate and frequent data could be undermined by major changes in the farming environment and examples of this have been cited in the previous section. While precision systems are employed to increase control over variability, aspects of the farming environment are also highly uncertain and uncontrollable, such as weather and cost of off-farm feed sources. Uncertainty presents a double-edged sword for precision systems: they could be utilised to maximise efficiency in the face of uncertainty, for example increased control over supplementary feed use; or the value of precision management could be undermined by environmental impacts, for instance precision pasture management being rendered impotent due to drought.

6.4.4 Relative importance of learning effort

While it is understandable that new users of PDF-ICT might focus on the technology rather than its associated learning requirement, it is surprising that experienced users reflected a similar focus. Learning effort was considered of secondary importance by these farmers compared to acquiring the correct technology characteristics. While the degree of learning effort associated with dairy ICT was important to farmers, experienced users had confidence that they could adequately master a complex system.
The low relative focus on learning effort could be interpreted as an indication that such systems are easy to learn. However it is more likely to be a reflection on the learning effort required to achieve basic competency with PDF-ICT. In comparison the learning effort associated with more advanced use and comprehensive integration of PDF-ICT into farm management systems would show a much steeper curve. Also, more abstract forms of data have a higher associated learning effort, for example using cow activity data derived from pedometers. The link between peaks in cow activity and their oestrus status can be subtle and requires more skill than determining which cows have dropped milk yield by 20%. Future precision dairy systems will pose more challenges in terms of minimising associated learning effort as an increasing array of complex sensors becomes commercially available and as more computer-based farm management time is required. Increasingly retailers will need to focus on the learning challenge rather than on the material technology component of precision dairy systems.

The attitude toward learning effort also suggests that farmers place a low value on ICT-related learning. Whereas many farmers pay to send their children to boarding school, there is an expectation that their own learning be practice-based with low or no financial cost associated. Yet the provision of training for precision dairy systems has some significant costs, especially where training is delivered one-to-one on farm. In the conjoint study participants indicated a willingness to pay to ensure a faster and easier learning process, yet in subsequent discussions on the topic they expressed reticence to pay additional money when already making a significant investment in precision devices. In order for farmers to build an appreciation of the value of the associated learning it could be explicitly itemised in the overall contract, rather than implicitly factored into retailer margins.

6.4.5 Employee capacity building with precision systems

Efficient and effective learning processes and management adaptation have a major impact on the level of information utilisation and incorporation in farm management practice. However, in addition to the role of people in technology systems it is also important to address the importance of these technology systems to the people who work on dairy farms. The interaction of farm staff with
precision dairy systems was mentioned by farmers in relation to tolerances for error and learning effort. Their views around the staff-technology interaction were divergent: some thought precision systems were a good way to ‘idiot-proof’ for unskilled staff, while others saw such systems as a way of making dairying a more exciting and modern career option.

Precision dairy systems provide an opportunity and a challenge for employee capacity building throughout the dairy industry. The industry is currently struggling with staff recruitment due to rural labour shortages (Dairy Australia 2007) and the increased use of precision dairy systems offers an opportunity for addressing this issue. However, this presents a challenge for training structures at both a farm and industry level to facilitate ICT capacity building. Employees have to be viewed as part of the precision system, rather than extraneous features whose interaction with new technology should be limited. Greater emphasis should be placed on promoting and facilitating expanded roles of dairy employees in precision dairy systems.

6.4.6 Risk profile of information use

A major driver in construction of precision dairy systems is the risk profile associated with the intended use of the data collected. For example when assessing their level of comfort with EID inaccuracy, a farmer will consider the level of risk associated with incorrect cow identification. As the perceived risk associated with an EID-related mistake increases so do farmer expectations regarding system accuracy, or alternatively the less likely farmers will be to rely solely on one form of identification. This concept is illustrated in Table 6.9 with seven different management uses for PDF-ICT and the associated risk from a management decision based on incorrect EID.
Table 6.9: Examples of risk associated with incorrect cow identification given different management use of PDF-ICT

<table>
<thead>
<tr>
<th>Data</th>
<th>Management use</th>
<th>Potential risk* from incorrect ID</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Treated cows - Database record</td>
<td>Alert: Antibiotic cow</td>
<td></td>
</tr>
<tr>
<td>Change in conductivity</td>
<td>Alert: Potential mastitis cow</td>
<td>✓</td>
</tr>
<tr>
<td>Cow status - Database record</td>
<td>Alert: Dry cow</td>
<td>✓</td>
</tr>
<tr>
<td>Change in activity (and milk yield)</td>
<td>Alert: Potential oestrus cow</td>
<td>✓</td>
</tr>
<tr>
<td>Cow status - Database record</td>
<td>Auto draft cow for AI</td>
<td>✓</td>
</tr>
<tr>
<td>Change in milk yield</td>
<td>Feeding to production (high grain system)</td>
<td>✓</td>
</tr>
<tr>
<td>Change in milk yield</td>
<td>Feeding to production (low grain system)</td>
<td>✓</td>
</tr>
</tbody>
</table>

* risk is defined here as the potential for an incorrect action to result in reduced cow health, cow production, or financial loss.

The conjoint exercise highlighted the different tolerances farmers hold for accuracy and frequency in the components of precision systems. These tolerances can be closely tied to the risk profile associated with the intended use. The original purpose of the technology can impact on the tolerance for error. For example, a farmer who invested in an EID-based system to replace staff in certain tasks will expect a greater level of system performance than one who views it as ‘just another tool’. The level of system trust will also bound a farmers initial precision farming goals, with high trust in system accuracy leading to higher expectations of technology operation. The research described in this chapter provides a potential tool for retailers to ascertain the level of acceptable error that their potential clients have, and then use this knowledge to adjust client perceptions of precision devices before investment. By determining the error threshold, through a conjoint analysis-like tool, retailers can also construct a plan to help farmers adapt technology and farm management practice during the early learning phase.

6.5 Summary

The research described in this chapter addressed the question: ‘how much precision is enough?’ with respect to the frequency and accuracy of data collected
within precision dairy systems. The relative importance of learning effort was also investigated to provide a holistic picture of the important factors in on farm construction of precision dairy systems. Research findings are summarised below in respect to the research questions.

1) What trade-offs do farmers make in the development of their precision dairy systems when time and money are limited?

When forced to select between imperfect choices to construct precision dairy systems, farmers preferred higher electronic identification accuracy and data frequency over milk yield accuracy. However, when making choices around learning effort farmers preferred systems that were faster and easier to learn, and they were prepared to pay to achieve this.

2) How important is accuracy and frequency of data when making feed allocation decisions?

First and foremost farmers stressed the need to accurately identify cows as a basis for automated allocation of supplementary feed. However, on farm practice adaptation was able to correct for minor inaccuracies. The importance farmers placed on data accuracy was related to the risk associated with making a wrong decision. Tolerance for error was smaller in higher risk scenarios.

3) What trade-offs will users make when faced with high learning requirements in the construction of their precision dairy system?

The learning effort associated with precision dairy systems was secondary to farmers constructing a system containing desirable material technology characteristics. Farmers wanted systems that they could learn to use quickly in order to start making a return on their investment and they were prepared to pay for training support to ensure a rapid learning process. Future development of precision dairy systems must not only take into account the need for rapid adaptation into farm management but also ongoing learning development to unlock more advanced PDF-ICT use. Learning must also be promoted as a commodity with its own value,
The findings from the conjoint analysis match well with observations from the six farm case studies indicating that the conjoint tool design elicited a good representation of the factors important to farmers in constructing precision dairy systems. Even in the learning effort scenarios where more cognitively complex concepts were presented farmers were able to find logical methods of expressing key criteria which would provide satisfaction in their system. While the conjoint approach shows potential, retailers and researchers in the precision dairy field need to build on this exploratory research to provide more rigour to the method.
7. Conclusion

7.1 Introduction

Precision dairy farming represents an evolution of dairy farm management practice. The concept of increased management control, central to the definition of precision farming, is inherent to dairy farming practice in general, both contemporary and historical. The challenge presented to farmers surrounds the shift from subjective or tacit based management to decision making on objective grounds. It also involves the use of data and ICT in an information intensive approach to management. This is where the management evolution occurs and where farmers are required to adapt and innovate. In this thesis the process of adaptation and innovation in precision dairy systems was investigated. The research approach adopted was aimed at providing a rich picture of what actually occurs on Australian dairy farms during implementation of precision technologies.

In Chapter 2 of this thesis the following definition was proposed for precision dairy farming:

*The use of information and communication technologies for improved control of fine-scale animal and physical resource variability to optimise economic, social, and environmental farm performance.*

This broad definition comprises three key aspects: systems based on ICT, with improved control as the aim, and where variability is the feature over which control is being sought. Adoption of precision dairying occurs as a continuum, rather than as a specific mindset change. The concept can be applied to any aspect of dairy farm management including pasture management, cow production, and cow health.
In Australia the commercial application of precision dairying exists primarily in the guise of individual cow management. Such systems, termed PDF-ICT in this thesis, range from ‘entry-level’ to ‘advanced’ and can represent a significant investment for dairy farmers. While the exact extent of PDF-ICT use is unsure, recent estimates suggest 10% of Australian dairy farmers employ some form of the technology for individual feeding purposes (Lubulwa & Shafron 2007). General adoption of ICT on Australian dairy farms has been slower than other industries but increased use of ICT can be expected as a result of developments in precision dairying technology. This is highlighted by current major Australian-based research projects assessing precision dairy-related tools such as automated milking systems, rumen boluses, and precision pasture measurement technologies.

The implementation of precision dairying suffers from a similar problem observed in the application of the precision farming concept to the arable and viticulture sectors, where the significant learning costs and adequate establishment of learning networks have not been addressed (Cowan 2000; Harsh 2005). Researchers and retailers of PDF-ICT tools have taken a techno-centric approach to precision dairying where concerted effort is placed into development of material technologies without sufficient consideration of issues around farmer adaptation and learning. The research described in this thesis aimed to explore the social factors involved with the on-farm application of the precision dairy concept using a precision dairy systems paradigm. The use of qualitative research methods enabled a rich picture to be built of the development of precision dairy systems within a commercially realistic context.

In this chapter the research findings are summarised with respect to the overall research questions. The findings are contextualised through a discussion of their implications for users, retailers, and developers of precision dairy systems.

7.2 Adapting to the change in knowledge management

At the heart of the learning challenge associated with precision dairy systems is the shift in knowledge management processes for farmers. Use of ICT necessitates a change from tacit-based practice to more explicit processes due to
the need for objective decision-making parameters within PDF-ICT decision support systems. Precision dairy systems are based upon intensive data collection, on both a temporal and spatial scale, which in itself constitutes a change in management practice for many farmers.

PDF-ICT systems effectively replace farmer practice on the lower rungs of the DIKW (data, information, knowledge, wisdom) hierarchy (Ackoff 1989) via incorporation of farmer knowledge within software programs. For example instead of using visual cues to identify cows in oestrus, the identification process is achieved through the use of pedometers and specific thresholds indicating abnormal cow activity. The aim is to streamline operational management and to introduce objectivity into the building blocks of decision-making. Farmers are therefore required to adapt their management practice to engage with the decision-making process at a different stage of the DIKW continuum. The management adaptation involves learning to interpret and use information, in the form of data processed according to pre-set parameters. The change in knowledge management in precision dairy systems takes two forms: firstly the conversion of a farmer’s tacit-based operational knowledge into explicit forms suitable for setting PDF-ICT parameters, and secondly the interpretation of explicit information produced by PDF-ICT and incorporation of it into meaningful management practice.

It is at this two-way tacit-explicit interface that the learning process for users of PDF-ICT is centred. The key finding of this thesis is that learning and adaptation around this interface involves the development of learning networks or communities of practice. The strength of this community, and therefore the extent of knowledge creation, is dependant on the links between actors in the community.

**7.3 Learning processes in Australian precision dairy systems**

The case studies of six farm businesses formed the backbone of this study and highlighted an obvious yet fundamental feature of learning in precision dairy systems – that every learning process is different. Learning is also an inherently
social process and farmers, even those in small family businesses, do not learn in isolation. PDF-ICT learning processes observed during this study lacked a focus on empowering self learning within farmers. There was evidence of a reliance on trainers and retailers as knowledge providers who were used as fire-fighters. An example was the ongoing use by one case study farmer of a learning support technician to create ICT-based report templates. While the technician provided a good service by creating these templates, and the farmer expressed a willingness to learn by reviewing the template structure, the pattern continued and the farmer did not learn to create his own templates. Through focussing on techniques and reasons for using report templates the retailer could have promoted self-managed learning and reduced their contact time with farmers as a consequence.

Current training programmes are focussed on the early learning phase of PDF-ICT use. In this study the diverse abilities of farmers to integrate ICT into their management systems was proposed to be a function of three core competencies: ICT skills; engagement; and knowledge transfer. Acknowledgement of these factors during the early learning phase can help retailers tailor their training efforts to specific farmer characteristics. Firstly new PDF-ICT users require a base level of ICT skill and the greater their computer literacy the better placed they will be to take advantage of the opportunities for precision dairying in their specific system. Further to this is the need for users to actively engage with the data and software, and it is through management adaptation that engagement occurs. In a practical sense management adaptation is exemplified by a farmer altering daily routines to include time at the computer, or by actively including staff in PDF-ICT learning and use. Reflective practice is a key part of the user’s paradigm shift, an area where PDF-ICT training can be enhanced.

Knowledge transfer is the final core competency associated with PDF-ICT integration. This primarily involves the flow of practice-based (tacit) knowledge between members of the farm management team, and between the management team and the PDF-ICT system. Thus on small owner-operator farms the issue of knowledge transfer is very different to that of a large farm enterprise with many staff. The subsequent challenges for learning associated with precision dairy system development need to be taken into account by retailers. The creation and
transfer of knowledge occurs at two levels, within the farm business as described above, and through linkages with actors and organisations outside the farm business. In this study these links were viewed in terms of the community of practice concept.

7.4 Learning networks in a developing precision dairy community of practice

Viewing the case study farms as part of a wider community of practice highlighted the importance of networks formed between community members and the associated transfer of knowledge. PDF-ICT users and retailers are foundation members of the community, and it is around them that primary learning interaction was focussed.

The learning networks observed in the case studies showed the strengths and weaknesses in the current community of practice. Retailers are constantly evolving their delivery of learning support, for example several months after the completion of the case studies one retailer constructed a webpage for users of their PDF-ICT product. The webpage represents an advance in knowledge transfer and includes free downloads of pre-built PDF-ICT reports, along with a newsletter focussed on PDF-ICT use. However, the learning support offered by retailers to the case study farmers was constrained by factors such as market size and geographical distance between users. These challenges increase the importance of networks between community members other than just the retailer to farmer link.

Improved precision dairy practice depends upon the development of social capital, the nurturing of new knowledge, and the ability to transfer this knowledge (particularly tacit knowledge) within the community of practice. In this study, the capacity to improve precision dairy system practice was found to be constrained by a lack of processes facilitating members to reflect on and question current practices. Increased participation in the community by consultants and farming systems researchers would aid in promoting reflective practice by challenging existing norms. This could prove a double-edged sword however with potential introduction of contradictory information for farmers to decipher. Continued
reflective practice could also help to engage those experienced precision dairy farmers who have reached a stable phase of utilisation but have untapped potential for more advanced use.

7.5 A knowledge-creating precision dairy community

The learning process for PDF-ICT users can be viewed at two levels. At a farmer-specific level is the concept of attending to core competencies for learning, while at a broader scale is the concept of a precision dairy community of practice.

The strength of a community of practice is in collective knowledge creation. In this instance knowledge creation involves facilitating specialist knowledge transfer and recognising farmers as co-developers of precision dairy systems.

Under current PDF-ICT research and development programs, dairy farmers, as the end users, are only explicitly considered as co-developers in the beta testing phase. From the users perspective, precision dairy technology is perceived to be ‘plug and play’ with potential inaccuracies understated. However this study has highlighted ‘bedding-down’ issues that occurred during installation of hardware and software on the majority of farms surveyed. As a consequence, most farmers adopting precision dairying technology experienced the need for adaptation of either the material technology or of their own management systems to compensate. This adaptation constitutes a continual on-farm development of precision dairy systems from which lessons could be harnessed for wider community benefit. Explicit acknowledgement of users as co-developers, along with a corresponding strengthening of feedback mechanisms to facilitate transfer of on-farm learning back to national and global retailers, are required to enhance knowledge transfer within precision farming networks.

Knowledge management is vital for a successful precision dairy farming community of practice and therefore knowledge created within the community should be viewed as an industry resource. Knowledge silos, where specific people or organisations hold a wealth of knowledge can act to constrain the innovative potential of precision dairying at an industry level. If significant human capital is
concentrated in one person, for example a technician, the community is at risk of losing knowledge if they leave. Fostering greater participation in the precision dairy community can help avoid such knowledge silos. An overtly proprietary approach to knowledge by retailers can also constrain innovation, for example where specific techniques and on-farm practice knowledge are contained within a client base.

7.6 Precision dairy systems at an industry level

At an industry level there is a need for cross-proprietor knowledge transfer via formal and informal networks. Opportunities exist for industry-good benefits from precision dairying data collected at the farm level, particularly in respect to herd improvement schemes. This information could be obtained via formal networks for data sharing but would require streamlined transfer systems and tangible incentives before farmers would invest their own time in participating. Industry organisations need to be proactive in creating a framework for formal knowledge transfer as it is an area already beset by proprietary-related constraints on transferring data between different software systems.

There is also an opportunity to strengthen informal networks at an industry level to disseminate precision dairying best practice. Currently precision dairy farmers operate in relative isolation from each other, despite efforts by some retailers to form user groups. The isolation can be largely attributed to geographical distance between users, and in particular between users of the same PDF-ICT brand. However the fundamentals of precision dairy systems are transferable across brand type, and more interaction between Australian precision dairy farmers should be promoted.

7.7 Facilitating innovative precision dairy systems

Chapter 6 provided a more detailed picture of the divide between the hard and soft technologies that constitute precision dairy systems. There was a focus by farmers on the devices of precision dairying rather than human systems components. Farmers also found the concept of differing learning efforts cognitively challenging but were still able to identify the time required to learn and ease of learning as
highly important factors. In fact farmers would pay money to obtain a system which was easy and quick to learn, primarily because to them ‘time is money’.

Facilitation of innovative precision dairy systems requires greater focus on the people who make these systems work in commercial reality. Hard technologies are the conduit for the real innovation, namely the management adaptation by farmers seeking efficiencies through increased control, to occur. The retailers and developers of precision technology need to understand the importance of what happens after installation on farm. The non-installation costs of precision dairy systems should be made explicit so that farmers can factor them in. An example is indicating the full cost of learning support so that farmers view it as a tangible resource, even if it is included in an overall contract price.

7.8 Research methodology and future research

In general the research method adopted for this study was appropriate for achievement of the stated objectives. However, some caution needs to be applied when considering extrapolation of research findings. While in-depth case studies provide a rich picture on the subject, this picture was restricted to a small segment of the Australian dairy industry. Participants were not selected at random, rather selection was primarily determined by project constraints such as timelines and funding. The participants could also represent early adopters of PDF-ICT, leading to bias due to their own technology-centric approach and consequent perception of the need for learning support. However, this research has provided an exploration of issues facing precision dairy farmers in Australia which can be used as a base for further research. The research method focussed on precision dairy systems from a farmer perspective and the role of retailers in the community was primarily viewed through the eyes of farmer participants.

As with most research, this study has raised many new questions which provide opportunities for future research. The role and perspectives of retailers requires further investigation, along with the possibilities for resolving the conflict between retailers’ commercial imperative and the ability for knowledge to be easily shared throughout the precision dairy network. Additionally, while this study identified the
importance of a systems approach to implementing precision technology on farm, further work is needed to determine practical methods for achieving it.

### 7.9 Final comment

In this chapter the findings from this study have been presented and contextualised. To draw the threads together, the original research questions (section 1.2) are revisited in respect to these findings:

1. **What are the processes driving farmer learning within Australian precision dairy systems?**

   Learning processes within precision dairy systems did not go far enough in empowering farmers to be self-learners. Acknowledgement of three core competencies (ICT skills, engagement, and knowledge transfer) for farmer integration of precision dairy practice would help retailers tailor training to specific farmer characteristics. Current learning support structures are inadequate for effective PDF-ICT learning on farm. The acknowledgement of learning as a valuable commodity begins before installation, in discussions between retailers and their farmer clients. These discussions could take the form of a learning contract, where an assessment of specific learning styles and core competencies associated with the farmer and other staff members is undertaken. Additionally this process would provide an initial map of the available support team including local retailers and knowledgeable farmers, and initiate networks with learning resources nationally and internationally. Potential strengths and weaknesses of each new client in respect to learning processes can therefore be identified.

2. **What is the role of on-farm adaptation in development of precision dairy systems in Australia?**

   A focus on material technology in precision dairy farming ignores the role of farmers as co-developers of precision dairying systems. On-farm adaptation of material technology, and precision dairy practice, is the key to development of these systems. The practice-based knowledge created by farmers is where the
precision farming goals of increased farming system control and increased efficiency of production are met.

In this study it was apparent that farmers were adapting their practices to suit the newly installed PDF-ICT devices. Prospective users may not predict the need for such adaptation, instead expecting the new devices to fit seamlessly into their existing management system. A PDF community of practice is vital to facilitate the adaptation process for new users. The adaptation process is not currently well understood and further research is warranted to investigate how farmers may extract most value from PDF systems. Such research needs to work in conjunction with a community of practice, learning from existing knowledge while helping to spawn new knowledge and practice.

3. What are key factors for the development of innovative precision dairy systems in Australia?

Development of innovative precision dairy systems relies on recognition of farmers as co-developers. Further to this, innovation is driven not just by farmers but by the network of people who operate around them in a community of practice. A community of practice approach can form the basis for development of innovative precision dairy systems. With the current small PDF community in Australia there is a consequent shortage of skills and experience. Strengthening the linkages between community members, and facilitating knowledge transfer around the community (for example from farmer to retailer to developer) is the key to innovation in precision dairy systems. Linkages also include enabling smooth data transfer around the community. Data captured on-farm has value for the wider industry, however currently data transfer is restricted by incompatibility between different software platforms and proprietary controls. Industry organisations must play a guiding role in creating protocols which free up data transfer.

People are the key to precision dairy systems, and while the research and development focus on material technology components continues, inefficiencies in
adoption and integration of precision technologies will remain. Costs are incurred in the innovation process, including opportunity costs of time during learning and tangible costs associated with management adaptation. These costs need to be emphasised by retailers prior to farmers investing in the precision technologies. The way forward for precision dairy systems, and presumably in all forms of precision agriculture, relies upon seeing technology as a socially-constructed system rather than as discrete hardware and software. Innovation in precision dairy systems is built around co-development of knowledge between technology developers, retailers, and farmers. Findings of this study emphasise the need to focus on co-development via recognition of the linkages between people, and pathways for knowledge transfer. Learning processes are an important development focus and it is here that social research has a particular role. The ongoing challenge is to construct methodologies which support the learning process, such as the adaptation of conjoint analysis for use in application of precision farming.
References


Bryant, L. 1999, *Computers on the farm: Farmers’ usage patterns and impact on farm management*, Rural Industries Research and Development Corporation, Canberra, Australia.


Daberkow, S. G. and W. D. McBride 2003, ‘Farm and Operator Characteristics Affecting the Awareness and Adoption of Precision Agriculture Technologies in the US,’ *Precision Agriculture*, vol. 4, no. 2, pp. 163-177.


Gummesson, E. 2000, *Qualitative methods in management research*, Sage, Thousand Oaks, California, USA.


Jarvis, P. 1987, Adult learning in the social context, Croom Helm, New York.


Kolb, D. A. 1984, Experiential learning: experience as the source of learning and development, Prentice-Hall, Englewood Cliffs, New Jersey, USA.


Publication No. 91. pp. 147–150, Wageningen Academic Publishers,
Wageningen.

Lave, J. & Wenger, E. 1991, Situated learning: legitimate peripheral participation,

Leeuwis, C. 1993. Of Computers myths and modelling, The social construction of
diversity, knowledge, information and communication technologies in
Dutch horticulture and agricultural extension, Department of
Communication & Innovation Studies, Wageningen Agricultural
University.

vol. 14, pp. 319-40.

Lowenberg-DeBoer, J. 2003, A Glimpse of Precision Agriculture in Australia,
SSMC Newsletter March 2003. Site-Specific Management Center,
Purdue University, accessed 12 December, 2007, from
<http://www.agriculture.purdue.edu/ssmc/newsletters/March03_Glimps
eofPrecisionAgricultureAustralia_gregedit1.htm>

Prepared for Dairy Australia, Australian Bureau of Agricultural and
Resource Economics, Canberra, Australia.

Lynch, T., Gregor, S. & Midmore, D. 2000, ‘Intelligent support systems in
agriculture: how can we do better?’ Australian Journal of Experimental

MacKenzie, D. & Wajcman, J. 1985, The social shaping of technology: how the
refrigerator got its hum, eds. D MacKenzie and J Wajcman, Open
University Press, Philadelphia, USA.


Reid, T. 2003, ‘Individual animal management in the dairy industry: where have we come from? Where are we going to?’ *Wool Technology and Sheep Breeding*, vol. 51, pp. 159-160.


Sankey, S. 2002, Where is time spent on dairy farms? South Island Dairy Event, 

Schmoldt, D. L. 2001, Precision agriculture and information technology,’ 

Schön, D. A. 1983, The reflective practitioner: how professionals think in action, 
Basic Books, New York, USA.

Shephard, R. 2004, Automatic milking system (AMS) research applicable to the 
Australian Dairy Industry, National Milk Harvesting Centre, Ellinbank, 
Australia: 57.

Smith, M. K. 2001, Chris Argyris: theories of action, double-loop learning and 
organizational learning, the encyclopedia of informal education, 

Smith, M. K. 2003, ‘Communities of practice’, the encyclopedia of informal 
education, accessed 15 January, 2008, from 

Spahr, S. L. and E. Maltz 1997, ‘Herd management for robot milking,’ Computers 
and Electronics in Agriculture, vol 17, no.1, pp. 53-62.

Spilke, J. and R. D. Fahr 2003, ‘Decision support under the conditions of automatic 
milking systems using mixed linear models as part of a precision dairy 

Stafford, J. V. 2000, ‘Implementing Precision Agriculture in the 21st Century,’ 


and use of a dairy management information system in The Netherlands,’ *Agricultural Economics*, vol. 23, no.1, pp. 79-86.


Weick, K. E. 1976, ‘Educational organizations as loosely coupled systems’, 

Goodman’, Paul S. (ed.). Technology and Organizations Jossy-Bass 
Publishers, New York, USA.

Wenger, E. 1998, Communities of practice: learning, meaning, and identity, 

Wenger, E. 2004, Knowledge management as a doughnut: Shaping your 
knowledge strategy through communities of practice. Ivey Business 

Williams, R & Edge, D. 2005, ‘The social shaping of technology’, in David Preece, 
Ian McLoughlin, Patrick Dawson (eds.) Technology, Organizations and 
Innovation: Critical Perspectives on Business and Management, 
Routledge, USA.

Wolfe, R. A. & Cooper, R. B. 2005, Information processing model of information 
technology adaptation: An intra-organisational diffusion perspective. 
Databases for Advances in Information Systems, accessed 18 August, 
2007, from <http://www.cis.gsu.edu/~dbase/>

Whyte, D. S., Orchard, R. G., Cross, P. S., Frietsch, T., Claycomb, R. W., & Mein, 
a better understanding. Lelystad, Wageningen Academic Publishers, 
Netherlands.

Yin, R. K. 2003, Case study research: design and methods, Sage Publications, 
Thousand Oaks, California, USA.
Appendices

Appendix 1: Example of questions in case study interviews

Below is an example of the questions asked during interviews with case study participants. Questions were adapted to suit each individual farmer and account for changes in their PDF-ICT experience.

Appendix 1a: Initial interview guide

Primary aims of interview
- To set a base to track changes from PDF-ICT use
- Identify goals and expectations for the system

Two main issues
- Farm management team learning to use system
- Use of the information collected by the farm management team and their advisors

Describe future herd management
- What components do you intend to install (reasons for these additional components of the system)
- Goals for system, reasons for putting it in
- What information will it collect
- What capabilities/skills are being developed to use the system

a) Farm and farmer characteristics

1. To start with, can you tell me about your farm?
   - Number of cows in the milking herd
   - Farm size (ha)
   - Enterprises
   - Shed type and size (rotary, herringbone etc) (number of clusters)
   - Labour units (job descriptions/specific roles/full or part time)
   - Length of time farming?
   - Management experience/educational background?
   - Who are the decision-makers?
   - Who is primarily responsible for herd management?
   - How would you describe your current farm state?
     ☐ Going more intensive
b) Herd management and collection of information

I’m interested in how you carried out herd management prior to using automation. The aim of the next questions are to try and get an idea of how herd management changed under automation.

2. How do you currently monitor the production and health of your cows?
   Prompts: Performance monitoring, Health, Heat detection, Feeding decisions, Culling decisions
   Prompt: Parameters for decision making

3. What information do you use to make herd management decisions?
   Example: Herd test results, vet checks,

4. How do you currently get this information?
   Prompt: Off-farm sources, friends/advisors
   Prompt: Pay for information

5. What kind of information do you record about your farm?
   Prompt: Written or electronic?
   Prompt: How often is it recorded?
   Prompt: Extent of use of computers?

6. Is there a seasonal aspect to your information requirements?

c) Purchasing the technology

7. What factors influenced your decision to purchase this new system?
   Prompt: Sales advice, family, friends
   Prompt: Previous experience with technology?
   Prompt: Change in farm size or goals, new shed

8. What information will the system collect? (relate to q3 & 6)
   Prompt: Production
   Prompt: Health

9. What impact do you expect the new system to have on your herd management?
   Prompt: Streamlining of data, Record keeping, keeping an eye on cows

10. What are you anticipating when will be required to get the most out of the technology?
    Prompt: Previous experience with similar technologies
    Prompt: Training already received
    Prompt: Issues with timing of installation with farm management demands?
Appendix 1b: Final interview guide (example)

1. Review previous information collected

**History of software use**
- Ration sheets, staff roster (Excel)
- MYOB for accounting
- Dairy Data (1995)
- OnFarm (1997)
- May use paddock management program

**Sources of farm management information**
- VicDairy-l email list
- Nutrition consultant
- Used to be involved in discussion groups, but not currently
- Soil tests

**Expectations of technology**

**Reasons for DP purchase**
- Fitted easiest into shed
- More reliable meters than Eli
- Local service and proven operation in district

**Expected uses**
- Use ICT-1 to find exceptions, those cows with something wrong
- from one herd of 900 cows, to 900 herds of one cow
- Use milk yield to highlight health issues
- Use of historical records
- Drafting
- Alerts for low milk flow and conductivity will be useful

**Expected performance of technology**
- ?

**Farm goals**
- 1000 cows milking 10,000 litres (650-700kgMS/yr)
- Focus on high milk protein levels

**Labour**
10.5 FTE
- Mr D’s role is A.I., some milking, in the shed most mornings
  - Likes to promote from within because people know the system
  - Talks to staff to see there are no issues
- ‘Shed manager’
- 1 worker fulltime mechanic/maintenance
- 1 worker (0.75 maintenance and 0.25 milking)
- other workers involved in milking and feeding
**What is ICT-1 used for?**

**Operational**
- Visual and voice alerts (fresh cow, treatment, dry cow)
- Heat prediction (based on time since last cycle)
- Drafting from pit or computer
- Herd test?
- Alert for cows not doing 30l with 21 days of calving
- Conductivity/milk yield graphs as aid for mastitis check or heat check

**Tactical**
- **Dry-off:** $5.50 dry-off report (Trainer-1 helped, used to be done manually in Excel)
- **Feeding:** Milk yield determines feeding rate (via nutritionists advice)
- **Culling:** *Any use for deciding on cow to cull?*
- **Breeding:** *Historical records for AI strategy?*
- **Health:** *Used to pre-empt health problems?*

**Risk management processes**
- Cups-on operator places markers on platform to indicate mastitis etc
- *Tail paint still?*

2. **Three key things I’ll take away (discuss)**
   - Previous experience with management software meant farm management adapted to ICT-1 quickly, however previous software still has some more favourable components.

   - Training/support could have included more farm-specific attention, ICT-1 struggled to comprehend the problems until they spent more time on the property during milking. Some advice and training has been contradictory between ICT-1 staff.

   - Mr D’s analytical skills have lead to more advanced use of software than other users, but a disjoint around the shed manager (with Mr D and staff) has hindered even greater utilisation for farm management decision making.

**Other points**
- minor glitches (computer crashing, milk data irregularities, drafting issue) have held back full operation of system
- conductivity is used only as an aid, not a primary detection tool
- if investing again you would not purchase this technology (different brand, or not at all?)

3. **Learning Style**
   Complete learning style list
   Review (do they agree, how this might relate to the training they received and how they learned about the software?)
4. Decision processes
   Tweak the process diagrams
   What they use the technology for in these decisions?
   What is good or bad about the technology?

5. Purpose and expectation of technology
   Expectations, subsequent changes in expectations (particularly related to how
   things did or didn’t work), current description of technology

6. Attributes of technology
   What is frustrating about the technology/system?
   What would make a difference to this technology being useful?
   Explore links between problems and the way they make decisions (complexity,
   trust – how does this impact their use?)

7. Characterising management practice
   Differences in attention to detail
   Timing of operations
   Planning behaviour (rare to be caught out by surprises)
   Link between reports on the computer and management on the farm
   Investigate style of enquiry (how do they enquire about what’s going on on
   the farm?
   Look at how they map themselves re learning style (use as a conversation
   starter)
   Do they critique themselves
   How do they stand outside themselves and reflect on their practice?
Appendix 2: Conjoint exercise one interview cards

Below is the cards used for the conjoint analysis exercise one with farmers as described in Chapter 6.

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Appendix 3: Conjoint exercise two interview cards

Below is the cards used for the conjoint analysis exercise two with farmers as described in Chapter 6.

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<td>Cost of support</td>
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<td>Time to learn (hrs)</td>
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<td>Cost of support</td>
<td>No cost</td>
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</table>
Appendix 4: Post-interview self evaluation form

Below is an example of the post interview evaluation form used by the researcher after every case study interview.

1. 10 main points to come out of interview?

2. General thoughts about the interview?

3. In general, how did the interview go?
   - location, timing, your feeling of how it went

4. Analysis of the information received
   Check to see my notes cover what was said, is there anything else you can think of?

5. Analysis of interview technique
   Do you think you built rapport (yes/no, why/why not?)
   Do you think the interview went well (why/why not?)
   Did you feel you got all the information available?
   What topics came up that surprised you?

6. Were there any issues regarding the questions?
   Did you get through all the questions?
   Did the question sequence follow the flow of the conversation?
   Were there any questions that needed more explanation?
   Are there any other questions you asked or could have asked to elicit more useful information?

7. What was your influence in the participants learning and information management process?
Appendix 5: Plain language statement

'Using conjoint analysis to elicit responses on dairy farm information systems'

You are invited to participate in the above research project, which is being conducted by Dr David Chapman (supervisor), Dr Mark Paine (supervisor) and Callum Eastwood (PhD student) of the Faculty of Land and Food Resources at The University of Melbourne. This project forms part of a PhD research program being carried out by Callum Eastwood and has been approved by the Human Research Ethics Committee of the University. Your name and contact details were sourced through researchers and consultants in the dairy industry. The research is not affiliated with any dairy technology retailers.

The aim of this study is to investigate the relative importance of data frequency, data accuracy, and learning requirement associated with EID-based individual cow management systems. This project represents an opportunity to gain insights into the key components of herd management systems, and to help the dairy industry through improved development and support of such systems.

The commitment that we are seeking from you is participation in an interview lasting no more than 1.5hrs. The interview will involve ranking several different potential herd management systems based on your preference. Your rankings will be used to discuss the issues of data accuracy, data frequency, and learning requirements. With your permission, interviews will be tape-recorded so that we can ensure that your comments are recorded accurately.

We intend to protect your anonymity and the confidentiality of your responses to the fullest possible extent, within the limits of the law. Your name and contact details will be kept in a separate, password-protected computer file from any data that you supply. This will only be able to be linked to your responses by the researchers, for example, in order to know where to send your interview transcript for checking. In the final report, you will be referred to by a pseudonym. We will remove any references to personal information that might allow someone to guess your identity. However, due to the small number of people interviewed for this project it is still possible that someone may be able to identify you.

Once the report arising from this research has been completed, a brief summary of the findings will be available to you on request to the student researcher named above, through the Faculty of Land and Food Resources. The data will be kept securely in the Faculty of Land and Food Resources for five years from the date of publication, before being destroyed.

Please be advised that your participation in this study is completely voluntary. Should you wish to withdraw at any stage, or to withdraw any unprocessed data you have supplied, you are free to do so without prejudice.

Should you require any further information, or have any concerns, please do not hesitate to contact the researcher supervisor Dr David Chapman, on ph: 8344 7587. Should you have any concerns about the conduct of the project, you are welcome to contact the Executive Officer, Human Research Ethics, The University of Melbourne, on ph: 8344 7507, or fax: 9347 6739.
Appendix 6: Consent form

THE UNIVERSITY OF MELBOURNE

INSTITUTE OF LAND AND FOOD RESOURCES

PROJECT TITLE: Individual cow management – Case study: Farmer learning and decision-making

Name of participant:
Name of investigator - student: Callum Eastwood
Name of investigator – supervisor: Dr David Chapman, Dr Mark Paine

1. I consent to participate in the project named above, the particulars of which include an audio taped interview, which have been explained to me. A written copy of this information has been given to me to keep.

2. I authorise the researcher or his or her assistant to use with me the project referred to under (1) above.

3. I acknowledge that:
   (a) the possible effects of the project have been explained to me to my satisfaction;
   (b) I have been informed that I am free to withdraw from the project at any time without explanation or prejudice and to withdraw any unprocessed data previously supplied;
   (c) The project is for the purpose of research
   (d) I have been informed that the confidentiality of the information I provide will be safeguarded subject to any legal requirements
   (e) I am over the age of 18 years

Signature ____________________________ Date ________________

(Participant)