

Understanding Expert Systems Applications from a Knowledge Transfer Perspective

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Abstract

Expert systems were introduced more than two decades ago but their effectiveness and success are still in debate. This paper attempts to make a contribution to the better understanding of expert system applications from a knowledge transfer perspective. The paper argues that an expert system application is knowledge transfer using Information and Communication Technologies (ICT). Underpinned by knowledge transfer theories and through a series of empirical investigations of agriculture expert system projects, the study recognises the importance of human interactions in the expert systems implementation process. Based on the evidence collected, a number of key players are examined. These are; knowledge provider/sender, knowledge engineer, knowledge extensionist and knowledge recipient. The paper represents a first attempt to introduce and acknowledge the role of a knowledge extensionist in the ICT-based knowledge transfer process. The name “extensionist” is borrowed from previous literature and describes an actor whose role is an intermediary in supporting transferring knowledge towards the knowledge user. Findings demonstrate the significant contributions made by extensionists to the success of expert systems applications. It is argued that the rigidity and limitation of ICT based knowledge transfer can be significantly reduced with the involvement of close human interactions towards the knowledge recipient.

Keywords: knowledge extensionist; expert system; knowledge transfer; agriculture; China.

1. Introduction

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The main function of an expert system is to mimic expertise and distribute expert knowledge to non-experts. The rapid development of Internet technology has changed the way that an expert system can be developed and distributed, but the distribution of expert systems to a large scale of end users can be challenging in terms of both effectiveness and efficiency. From a knowledge transfer perspective, it is argued in this paper that an expert system application is a knowledge transfer process in which expert knowledge is captured by a computer system (ICT) and delivered to non-expert recipient. It is believed that looking at expert system applications from a knowledge management point of view could benefit researchers and practitioners working in either the expert system or knowledge management domains.

The traditional knowledge transfer approach is frequently criticised for its rigidity and bureaucracy because all knowledge transfer activities solely rely on the face-to-face communications from a centralised extension agency down to local recipients. After a few layers of people-to-people contact, knowledge can be easily lost or distorted. At the same time, knowledge transfer cannot achieve a great deal of efficiency by limited source when dealing with many users.

“Sharing knowledge is power” (Liebowitz, 2001). This is especially true when agricultural expert systems are introduced to farmers in the developing world. In many developing countries the agriculture sector remains the largest employer in the country and agricultural productivity is one of the major concerns for the country’s economy. Agricultural knowledge extension is seen as an effective solution for improving agricultural productivity. The word “extension,” in this context, derives from an education development in England during the 19th century when Oxford University and Cambridge University attempted to serve the rapid expansion of educational needs from society. It was called “university extension”. In the early 20th century, the word extension was applied to describe the transfer of knowledge and technology to serve the needs of rural development by American land-grant universities (Jones & Garforth, 1997). The rapid development of ICT, such as agricultural expert systems, brings new opportunities to the agricultural extension methodology (Rees, Momanyi & Wekundah, 2000). From a knowledge transfer perspective an agricultural expert system is a knowledge transfer medium, through which advanced knowledge is encoded and transferred to a recipient, who can learn and benefit from the knowledge transferred.

Expert system applications may involve a large number of users with diversified application scenarios. For example, a web-based expert system project in China can have potential impact on millions of farmers. Because of the large scale of the application, the application scenarios may vary in accordance with specific local farming conditions. The success of large scale expert system projects in the agriculture sector faces a number of challenges: 1. the large knowledge gap between the knowledge provider and the farmers, as sometimes, poorly educated farmers are not able to absorb the knowledge delivered to them nor follow the advice provided by the system; 2. the sheer number of users involved in using the expert systems; 3. physical distances between the knowledge provider/knowledge engineer and end users; 4. complex and diversified application contexts. Through empirical investigation into current ES applications in Chinese agriculture sector, it is evident that those challenges can be significantly reduced through the use of knowledge extensionists. This paper aims to analyse expert systems application cases, identify the roles of knowledge extensionists and report their contributions to the success of expert systems from a knowledge transfer perspective.

2. Literature Review

An expert system is “*a system that uses human knowledge captured in a computer to solve problems that ordinarily require human expertise*” (Turban and Aronson, 2001). Expert systems are considered as a branch of artificial intelligence (AI) because the method of problem solving is predominantly based on heuristics (Darlington 2000). Durkin (1996) reports that many organisations have leveraged the technology to increase productivity and profits through better business decisions. Although there have been reports of ES failures (O’Keefe & Rebne, 1993; Wong, 1996), research (Yoon *et al*, 1995; Kunnathur *et al*, 1996) shows that many companies have remained enthusiastic proponents of the technology and continue to develop important ES applications.

The early applications of expert systems were standalone applications based on mainframe, AI workstation or PC platforms. The Internet offers an ever-expanding set of capabilities and a web based ES is capable of offering much more than traditional ES. Perhaps the most successful example is web-based legal ES reported by Bodine (2001), which enable law firms to collect hundreds of thousands of dollars in subscription fees from clients who use their advisory services. PT Consulting Partners in USA (2005) reported that they have helped its clients to build a number of successful web based ES which have brought significant benefits to the client

company. Grupe (2002) reported a web based ES called Student Advisor, which is an online ES helping students to select an academic major.

From knowledge management point of view, an expert system application is a knowledge transfer activity using ICT. The objective of any knowledge transfer is to transfer the source knowledge successfully to the recipient (Cummings and Teng 2003). Brown and Duguid (1998) point out that knowledge transfer to a recipient who has a limited knowledge base will be difficult. Lin, Geng & Whinston (2005) develop a knowledge sender and recipient framework to classify knowledge transfer structures. They indicate that most literature implicitly assumes that knowledge transfer occurs under a symmetric complete structure. Within this structure both sender and recipient are underpinned by the same expertise and have the same knowledge capability. However, it is argued by the authors that, in practice, a sender-advantage asymmetric structure occurs commonly, within which the sender has a much better expertise and stronger knowledge capability, and so has an knowledge advantage over the receiver.

The mainstream ICT based knowledge transfer literature is focused on the business sector and examines inter- and intra-organisational knowledge transfer facilitated by ICT (see e.g. Pawlowski & Robey 2004). With the knowledge base and knowledge capability at similar levels, inter- and intra-organisation knowledge transfer can be defined as a symmetric complete structure. In expert systems applications, the end users are normally non-experts who are seeking advice and help from domain experts. It is evident that end users expertise and knowledge capability are much lower than domain experts. With the classification given by Lin, Geng, & Whinston (2005), it would be appropriate to regard expert system applications as a sender-advantage asymmetric structure.

Communication theory has been one of the fundamental bases in knowledge transfer research. It emphasises the critical players and their interactions during the knowledge transfer process (Szulanski, 1996). Based on communication theory, knowledge transfer is influenced by five basic elements: source, channel, message, recipient, and context (Szulanski, 2000). The process of knowledge transfer has been described as a two-stage process from the knowledge transmission by a sender to the absorption by a receiver by Garavelli, Gorgoglione, & Scozzi (2002), a multi-stage process by Santoro & Gopalakrishnan (2000), and multi-stage knowledge flow by Kim, Hwang, & Suh (2003).

The knowledge transfer intermediary has also drawn certain research attention and is described as an irreplaceable middleman of a transfer process for recombining past experience and leading towards new knowledge (Hargadon, 2002), or helping an organisation in procuring new knowledge (Hinloopen, 2004). Lack of intermediaries may be the one of the reasons leading to the failure of some ICT-based knowledge transfer projects (Matson et al. 2003). Pawlowski & Robey (2004) identify that IT professionals are committed to facilitating the knowledge flow across business boundaries for ICT based knowledge transfer. Meera, Jhamtani, & Rao (2004) also point out that local agricultural extensionists are important facilitators in farmers' access to computer applications for knowledge.

There has been a different understanding in knowledge transfer texts concerning the capability of ICT in transferring knowledge. There seem few doubts about the ability and efficiency of ICT in transferring explicit knowledge (e.g. Cummings and Teng, 2003), but considerable Debates have been raised about the transferability of tacit knowledge via ICT because tacit knowledge cannot be articulated, codified and be easily understood (Nonaka, Reinmoeller & Senoo, 1998). A simple dichotomy of knowledge into the explicit and tacit can be somewhat misleading for the study of ICT based knowledge transfer for two reasons. Firstly, the boundary between explicit knowledge and tacit knowledge is porous, flexible (Spender 1996), and confusing (Clark, Carter & Szmigin, 2000). A vague distinction of explicit and tacit knowledge leaves much room for researchers to find themselves with contradictory viewpoints. Some literature attempts to avoid a distinction between the two in their arguments. For instance, Blumentritt & Johnston (1999) insist that the human intelligent system is the only repository of knowledge and only information can be transferred with ICT. Hislop (2002) points out that ICT is effective in facilitating explicit knowledge transfer but tacit knowledge can only be transferred by face-to-face communication. Bolisani & Scarso, (1999) argue that ICT can transfer both explicit and tacit knowledge.

Secondly, being commonly defined by the school of management studies, explicit knowledge is challenged conceptually. Knowledge transfer does not mean that knowledge is moved as goods, instead, the recipient absorbs it by reconstructing their version of the new knowledge based on that transmitted (Sveiby, 1996). In a symmetric knowledge transfer structure, it is implicitly assume that electronically codified and transferred knowledge is explicit knowledge, as it will be understood and absorbed by a recipient. However, such implicit

assumption may be unable to explain knowledge transfer process in an asymmetric structure. Cowan, David, & Forey (2000) explains that the knowledge being “codified for one person or group may be tacit for another and an utterly impenetrable mystery for a third”.

To avoid the conceptual confusion, this paper attempts to divide the knowledge into ICT transferable and ICT non-transferable knowledge, which is broadly in line with the arguments of Boutellier, Grassmann, & Macho (1998), Cowan, David & Forey (2000), and Cowan (2001). ICT transferable knowledge is the knowledge that can be electronically codified and transmitted by ICT. ICT non-transferable knowledge is the knowledge that can only be transferred by face-to-face communications.

3. Research Method

To better understand the expert systems applications from a knowledge transfer process through expert systems, the key players involved, and the specific role of knowledge extensionists in the process, a case study approach was adopted. Field investigations and data collection were based on five expert system application projects in China’s agriculture sector. The expert systems offer technological knowledge on advanced farming methods and diseases prevention and treatment. With state key research institutes or universities as the project initiators, five ES projects are delivered at either regional or national level. The profile of five projects are summarised in table 1.

(table 1 is about here)

The case study method was employed in this research because it allows researchers to retain the “holistic and meaningful characteristics and real-life events” (Yin, 2003). In-depth interviews were a major data collection method. A total of 65 individuals were interviewed with between 10 and 15 participants from each of the five projects. The interviewees were selected based on the nature of their roles in the project. They include project manager, domain expert, knowledge engineer, computing system programmer, expert system applications facilitator (extensionists), and users (farmers). Some participants play dual roles in the project. To enhance the reliability of qualitative data, all in-depth interviews were either tape recorded or field notes taken immediately after the interview.

The interviews were not structured in nature and covered the following main questions: what is your role in the ES project? What is the knowledge source? Who are the recipients? What does a typical recipient like? Can you explain the ES application (knowledge transfer) process? What is your understanding of the role of an extensionist? What difficulties and problems you have experienced? What is your opinions on the effectiveness of the ES, why? etc. All interview data was finally transcribed into MS-Word. Triangulation of evidence was achieved by collecting project documents and conducting direct observations. In total 32 project briefings and reports were collected and examined.

To analyse the qualitative data collected from interviews, NVivo, computer-assisted qualitative data analysis software, was used. With the assistance of NVivo, an analyst's physical tasks can be taken over by the software for marking sequences of text by coding, and retrieving together all sequences of coded text (Bryman, 2004). More conveniently, in qualitative analysis it can be relatively easier to visualise the data by using the Model Explorer facility in NVivo. Different icons and shapes are used as the representation of themes with the links to represent the relationships. Diagrams produced in the Model Explorer are a powerful way of exploring and analysing the data and auditing the development of ideas (Gibbs, 2002).

4. Findings and discussions

The main purpose of case studies is to analyse the knowledge transfer process, the players involved and their roles in the transfer process. The following sections discuss the identified actors in knowledge transfer, the transfer process and the interaction among involving actors and the roles of the extensionist.

4.1. Expert system based knowledge transfer process

Inspired by the communication theory and its emphasis on the critical players and their interactions during the knowledge transfer process, this paper focuses on examining the key actors involved in the expert systems applications and their interaction and contribution to the knowledge transfer.

The expert system based knowledge transfer process was examined with the empirical evidences collected from the case studies. Figure 1 illustrates the knowledge transfer process from senders to recipients with the intermediary actors between them, such as knowledge engineers and extensionists. Two types of knowledge flow are identified, namely as ICT-transferable knowledge and ICT non-transferrable knowledge. The interactions between actors, and an actor with ICT systems are also clearly visualised. This framework is partly in line with a knowledge transfer framework proposed by Argote & Ingram (2000). They suggest that knowledge is embedded and transferred within a network that consists of three repositories: people, tools and tasks. In this study, people refers to human expert, knowledge engineer, extensionist and farmers; tools refers to expert systems; and tasks refer to activities undertaken along the transferring process by various people, such as knowledge acquisition, codification, absorption, internalisation, etc..

In all of the cases investigated, it is evident that knowledge extensionists play very important roles in facilitating the knowledge transfer. The long distances and widely scattered project sites do not permit knowledge engineers to contact farmers face-to-face. The complex local agriculture environment also does not permit the domain expert and knowledge engineer to cover all possible application problems. Local extensionists are trained jointly by agriculture experts and knowledge engineers. During the training process, the different versions of expert systems are finalised with the joint efforts of local extensionist, knowledge engineer and agriculture experts in response to different local needs. In the meantime, the training programme provides opportunities for extensionists from different regions to share and exchange knowledge that may be beyond the competence of the knowledge base embedded in an expert system.

(figure 1 is about here)

4.2. Actors involved in ICT based knowledge transfer

4.2.1. Knowledge provider (sender)

The knowledge provider for the five expert systems is mainly human domain experts. Depending on the context of different projects, knowledge acquisition approaches vary. For example, in ES-a and ES-b which are the development of a fruit farming and disease prevention system, the research institutions has no first-class experts available within the organisation, therefore, external experts and text based publications are the main knowledge source. Published sources help the knowledge engineer not only to develop his/her personal knowledge in the

domain, but also to reduce reliance on the domain expert.

In project ES-c, husbandry experts' contribution to knowledge is in an organisational setting. The project is a joint collaboration between an artificial intelligence research institute and an agriculture research institute. In project ES-d and ES-e, almost all knowledge was acquired from a group of aquiculture experts who were led by a chief expert. Thus, contrary to expectations, the field study finds that prior to the initiation of some specific projects a knowledge provider per se did not readily exist and had to be created from both individuals and published resources.

4.2.2. Knowledge receiver

A knowledge recipient is the system user or the knowledge recipient at the end of the knowledge transfer chain. In this study, rural farmers are identified as the knowledge user. The majority of Chinese farmers can be characterised as poorly educated and computer illiterate hence a large gap exists between knowledge senders and recipients. Therefore, knowledge transfer effectiveness through ICT poses a significant challenge.

Field investigations found that a large number of expert systems are installed in places accessible to farmers in each project location. Farmers report that an expert system enables them to access expertise and help them to improve agricultural production. In their words, computers bring them “*experts at the farm gate*”.

4.2.3. Knowledge Engineer

A knowledge engineer plays critical roles in expert systems applications. A knowledge engineer is normally responsible for building the knowledge based system (Giarratano & Riley, 2002). A knowledge engineer carries out knowledge acquisition, knowledge representation and codification, and system programming.

In the expert system projects investigated, the knowledge engineer actively worked with various domain experts for the knowledge acquisition and codification tasks. None of the knowledge engineering work was carried out by an agricultural expert. It is interesting to see that neither the agricultural expert nor the engineer are interested in playing the roles which they feel that they are not good at.

4.2.4. Knowledge Extensionist

This study represents a first attempt to introduce and acknowledge the unique role of an extensionist in the knowledge transfer in expert systems applications.

In the early literature, the role of extensionist was reported to transfer the knowledge and skills in a social network originally, and more recently in the agriculture sector. As the demand for the intensive involvement of domain experts increases, such an institutional setting is mainly beneficial to developed countries that have sufficient experts in the agricultural extension system. With insufficient agriculture experts and scarce investment, the practices of agricultural extension in many developing countries experience a high rate of failure.

The analysis of the expert systems applications shows that an extensionist is needed to facilitate the knowledge transfer activities and enhance the effectiveness of the applications. Various local organisations are found to have been directly involved in facilitating the application of agricultural expert systems in the local region. For example, the local applications of expert system in project ES-b, ES-c and ES-e indicate that expert system facilitators include various intermediary organisations at both private and public sector. In project ES-b, ES-c, and ES-e, it is found that knowledge engineers only have contacts with local extension agencies or other intermediary organisations.

In the projects at the local level there is a co-location of knowledge engineer and user, e.g. project ES-a and ES-d, and relatively small number of potential users compared with those at the national level. In these cases the knowledge engineer sometime has to play a dual role as a knowledge engineer and extensionist. In both ES-a and ES-d, knowledge engineers travel frequently between the systems development institution and the farmer's village to help farmers in system installation and application.

The experience gained and the information collected in our investigation demonstrates the need as well as the importance of the extensionist in facilitating knowledge transfer in expert systems applications.

4.3. Analysis of an extensionists' role

The investigation of the five projects finds that expert systems are being facilitated by extensionists from various organizations, such as:

- Public extension agency, e.g. local agricultural extension station, agricultural science park;
- Public science and education institution, e.g. agricultural polytechnic, agriculture college, agriculture research institute, rural evening schools;
- Local farmer community, e.g. farmer's agriculture association;
- Commercial organisations, e.g. agro-business companies; rural internet bars.

Analysis of the case study materials and the interviews clearly suggest that extensionists play four different roles. These are: a knowledge transfer intermediary; a knowledge sharing facilitator; a new knowledge creator; and a continuous expert system developer.

4.3.1. A knowledge transfer intermediary

Extensionists help to transfer the knowledge and sometime provide support beyond the capacity of an expert system. At the early stage of the expert system project, it was assumed a tailor made expert system will fully satisfy farmer's knowledge needs. The preliminary assumption was drawn from many farmers' expectation that: "The computer [expert system] can transfer knowledge without a discount (quality reduction)" At a later stage, it was realised that a complete knowledge transfer sometimes can only be achieved when both ICT transferable and non-transferrable knowledge are delivered to knowledge users.

In a sender-receiver asymmetric knowledge transfer structure, it is not a problem for ICT transferable knowledge being articulated, codified and transferred using ICT, but the local absorption of electronically transmitted knowledge sometimes may be difficult. Farmers may not be familiar with knowledge transfer process of expert system as pointed out by farmer Qin in ES-a:

"The computer [expert system] does not speak in a way as a real expert does. Questions it asks cannot be answered by me, and vice versa. If I talk to a real expert, I can easily explain my questions to the person".

Farmers may also find difficult to understand the explanation provided in a scientifically rigorous approach by an ES. For example, Farmer Zheng in project ES-c said:

"I am always puzzled with some suggests given by computer [expert system], for example, it says that my duck may have 75% percent possibility of having enteritis. So what shall I do with the 75% possibility? I really do not know".

The investigation found that a small number of expert systems are installed in an individual farmers' site and used by them without the assistance of the extensionist, but the majority of expert systems are installed in a village office or a community centre and used by farmers with the assistance of an extensionist. Various local organisations assign such tasks to staff who possess certain levels of both domain and IT knowledge.

Although the expert systems have been carefully adapted by extensionist to the local needs, many low educated farmers still find that it is difficult for them to understand the advice and instructions provided by an ES. Such difficulties can be better addressed by an extensionist with face-to-face communication. For example, Mr Li said:

“Farmers collect their information through their eyes and ears. To farmers, a picture is more meaningful than one hundred words, and a story is more meaningful than ten theories. Believe it or not, a farmer may get lost in a series of IF-THEN instructions.”

Another example is in ES-b, a series learning references paper, which is called locally “easy knowledge card”, is prepared by an extensionist for farmers. With the support of an expert system, selected knowledge items drawn from the expert system are reedited with the local language that farmers are more familiar with. In addition to textual explanation of those disease symbols, colourful pictures are added to illustrate the concept and descriptions.

The case studies also found that even when farmers learned how to deal with the disease from an ES, some of them still liked to confirm what they have learned from a computer with a local extensionist. It seems that some farmers would only trust the knowledge provided by an ES if it is backed up with an extensionist.

Knowledge transfer with ES can also be regarded as a learning process for farmers. As a result, learning is not a one off event but ongoing process. An extensionist is found important in facilitating a farmer's new knowledge application process. For example, farmer Liu in project ES-e said:

“I am not a slow learner, but you know we have to learn by doing. I assume the artificial fertilisation process for trout is easy to learn with the help of an ES, but it is not. You always find something is not covered by the computer (ES) when you try to do it. Thanks to Lao Xie [a local extensionist] for his 24 hours cell phone consulting service and his visit to my pond. Now I have mastered the process successfully with his timely help.”

Regarding the ICT non-transferable knowledge, it is contextually related and difficult to be transferred using ICT. For example, a human veterinarian expert Guo in project ES-c stated:

“When you diagnose a sick pig, you may comprehensively scan the circumstances it lives, its physical appearances, and its body movement. But to some extent, some facts only can be known when you are on the sites, e.g. smell, touching behaviour, etc.. To ensure the farmer to learn it accurately, we have to teach their local extensionist to learn it by direct observation and practice with my supervision. When they return to their villages, they may find appropriate cases and demonstrate such knowledge face to face to farmers”

An extensionist Mr Gong in project ES-c told the researcher:

“In our cow expert system, traditional animal acupuncture is demonstrated with some diagrams and pictures. But it is not easy as it is very experience based. Each time when farmers would like to try, I will teach them in person. In terms of finding the accurate acupoint, controlling the needle, perceiving the cow’s reaction...it is learned only by doing with your close watch.”

For more effective knowledge transfer, it can be argued that the use of an extensionist as a knowledge intermediary can enhance knowledge absorption and transfer to ensure completeness and effectiveness.

4.3.2. A knowledge sharing facilitator

The second finding of this research is the acknowledgement and identification of the extensionist as a knowledge sharing facilitator for fostering local farmer’s knowledge exchange activities in expert system applications. It is argued that knowledge on agriculture production is “locally and historically embedded and socially constructed” (Osbahe & Allan, 2003). With a dense population in the countryside, farmers are used to sharing knowledge via socially constructed knowledge sharing network. In project application sites, the expert system is introduced into such networks. Farmers are organised together with kinship members and friends for collective learning with the help of the local extensionist. In this case, an extensionist is identified with a role of knowledge sharing organiser and facilitator. For example, extensionist Xiao said:

“An efficient way to teach farmers in a village to use the expert system is to teach some smart and capable farmers to use it firstly. Then few guys of the first group are invited by me to teach the second group. As being familiar with each other, farmers know the best way to get the message crossed and share their experience

with their kinships and friends and help each other to use the system.”

This process is regarded as very useful as project manager Yang explained:

“Some less educated farmers are incapable users in determine what knowledge is useful when mass electronic knowledge suddenly available in front of them. We must send them a guide [extensionist] for an easy navigation in their knowledge seeking. When teaching swimming you can’t throw a beginner into an ocean alone in his beginning class, right? You know, our local extension station is like a safe swimming pool which has coaches (extensionists) who also organize them to learn from each other.”

4.3.3. A new knowledge creator

The third finding of this research is the acknowledgement and identification of the extensionist as a new knowledge creator to update the knowledge base with new knowledge. In the study of knowledge management, knowledge transfer is commonly associated with knowledge creation (Nonaka, Toyama, & Konno, 2000). This study offers evidence to support such an argument. It is found that extensionists are able to enhance the knowledge base with new knowledge or best of practice discovered by either themselves or farmers.

For example, in project ES-d and ES-e, newly introduced chemical medicines are suggested to farmers by the ES with clear instruction on the standard doses for the treatment. However, farmers sometime seem to use a higher dose than suggested for more significant effect. Extensionist Chen identified the risk of the application of the overdose and incorporated new knowledge he has collected for a better result of disease treatment. The new knowledge is about the use of a mixture of chemical medicines and traditional herbs. Green herbs are cheaply available and have less risk for product pollution. Similar examples are also demonstrated in other three projects. This kind of the knowledge creation by extensionist benefits the rural expert system users.

Extensionists also facilitate new knowledge creation by reporting new problems and cases back to knowledge engineers, so they can consult knowledge providers and develop solutions to the new problems. For instance, extensionist Zheng explained the interaction between knowledge engineer and extensionist for fostering new knowledge creation:

“Since some new farming or treatment techniques suggested by an ES can be expensive, farmers may be hesitated to adopt it. But some farmers applied a new method with a mixture of the newly introduced knowledge and the local indigenous one. Later, professors [knowledge engineers] became so interested in

such creativity in new methods that they asked me to collect it for them. When the system was upgraded he added this new knowledge item to the knowledge base. You see, professor and farmer jointly change a 'dead' technology into a 'live' one."

4.3.4. A continuous system developer

The fourth finding of this research is the acknowledgement and identification of the extensionist as a continuous expert system developer to update, modify and adapt the expert system to the specific local conditions and user needs. Field investigations showed that an extensionist plays an important role in helping the knowledge engineer to complete and validate the expert system for local applications. Local heterogeneity of agricultural systems and complexity of the biological systems are such that scientifically derived technologies cannot cope alone with the scale of the problem (Hall & Clark, 1995). What is of interest to the study is the approach of tailoring the expert systems toward an applicable one to meet the needs of diversified agricultural production. In field interviews, the words 'second time system development' appear frequently and interchangeably with the words 'system localisation', which refers to the continuous development of the expert system.

Although modern technological knowledge has brought advanced farming methods, continuous improvement on the technological approaches and their applications may ensure their fulfilment of the requirement of local farming communities (Weiss, Crowder, & Bernardi, 2000). All of the expert systems application projects investigated demonstrate the necessity of localising the expert system for local needs. They also all undertake localisation tasks either by involving knowledge engineers or local agricultural experts before the final systems delivery, or by providing the training to the regional extensionists on how to modify the expert system toward a successful local application.

For example, in ES-b, the knowledge engineer develops the standard expert systems for vegetables, fruits, crops, and husbandry production. Local extensionists are called in from various expert system facilitating organisations to attend the training programme delivered jointly by agricultural experts and project knowledge engineers. One of the major goals of the training programme is to teach all extensionists the skills of using the expert system development shell to modify the system for the specific local conditions. With the flexibility of the expert system shell, not only knowledge items, communication language and knowledge searching process can be modified, but also the knowledge base and system interface can be adjusted. Extensionists with stronger

computer skills and greater expertise can even be trained in developing a new expert system for a specific local application.

5. Conclusions

Expert systems provide an opportunity for developing countries to transfer agricultural knowledge to rural farmers by the mass duplication of the valuable knowledge of domain experts. However, effective implementation of expert systems cannot by itself override the disadvantage of the rigidity and narrow focus in transferring knowledge.

This paper makes a number of important contributions to a better understanding of expert systems applications: Firstly, from a knowledge management point of view, it points out that an expert systems application is a knowledge transfer process and attempts to look at ES applications using knowledge transfer theories and analysis. It argues that researchers and practitioners working in the ES domain can benefit from knowledge management theories and studies.

Secondly, the paper reviews the characteristics of expert systems using the Lin et al (2005) sender-receiver framework for knowledge transfer and recognises that ES-based knowledge transfer has the sender-advantage asymmetric transfer structure. In a sender-advantage asymmetric structure there is normally a significant gap of expertise and knowledge capability between the knowledge provider and a recipient.

Thirdly, through case studies, the paper reveals that when there is a huge knowledge gap between knowledge sender, i.e. experts, and knowledge receiver, i.e. farmers in this case, the effectiveness of knowledge transfer could be seriously jeopardised without adequate human intermediaries and social interactions. Findings confirm that in regard to transferring the remaining ICT non-transferable knowledge beyond the capacity of an ES, a face-to-face approach or rich contextual communication support is one way to reduce the gap. The paper argues that in ES applications, as a sender-advantage asymmetric knowledge transfer process, human actors and especially knowledge extensionists play an important role in facilitating both ICT-transferable and ICT-non transferable knowledge.

Through a series of case studies involving interviews with the main players in expert systems application projects, the research develops an expert system based knowledge transfer framework. In this framework, all key actors, their interactions with other human actors and the ICT system, and knowledge flows are clearly located and visualised.

Extensionists make significant contributions to expert system effectiveness. According to the findings, a knowledge extensionist can act as:

- A knowledge transfer intermediary to help reduce the knowledge gap and shorten the knowledge distance between the sender and the receiver.
- A knowledge sharing facilitator to help knowledge receivers share and learn knowledge through their local social networks.
- A new knowledge creator to enhance or extend the knowledge base with new knowledge.
- A continuous expert system developer to help adapt the system to the local needs.

Having formally recognised the role and the important contributions of the extensionists in ICT based knowledge transfer, issues related to the education and the training of the extensionists need to be addressed. Also, further research on the success factors affecting the expert system applications from knowledge users and extensionists' point of view should be examined.

Regarding knowledge theories, this study finds limitation in current taxonomy of knowledge properties. By simply dividing knowledge into the ICT transferable and non-transferable knowledge, there can be conceptual conflicts or confusion caused with respect to another common knowledge dichotomy, i.e. explicit and tacit knowledge. Explicit knowledge, by its definition, is easily transferred by using ICT, but the ICT's transferability of tacit knowledge remains debatable. Therefore, further research on the theoretical development of knowledge classifications, which are suitable for ICT based knowledge transfer systems, should be carried out.

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Table 1
The profile of five agricultural expert system applications projects investigated in the study

Project	Application domain	Development approach	Project initiator and system developer	Local facilitator	Target user
ES-a	Web based crop and fruit farming expert systems for rural Beijing farmers at the local level.	Knowledge engineer develops an expert system using an expert system shell-PAID 4.0. Domain knowledge are acquired and encoded into the system by the knowledge engineer.	State Agricultural Information Engineering Research Centre in Beijing Agriculture and Forestry Research Institute.	Expert system team members.	Farmers in the rural areas of Beijing. Potential users are 800.
ES-b	A group of web based crop and fruit farming expert systems at the national level.	Using the same expert system shell in ES-a. Domain knowledge are acquired and encoded by various local intermediary organisations for applications in different regions.	State Agricultural Information Engineering Research Centre in Beijing Agriculture and Forestry Research Institute.	Local agricultural extension stations, agricultural science parks, agricultural polytechnics, agro-business companies, local agricultural research institute, local farmer's associations, rural evening schools, rural internet bars.	Farming workers of modern farming demonstration farms in 20 provinces in north, northeast, northwest and southwest. Potential users are about 7 million.
ES-c	A group of web based poultry and husbandry farming expert systems at the national level.	Knowledge engineer develops an expert system using an expert system shell-DET. Domain knowledge are acquired and encoded into the system by local intermediary organisations for applications in different regions.	A collaboration between a State Artificial Intelligent Machine Research Institute and Anhui Provincial Academy of Agricultural Science	Local agricultural extension stations, and local agro-business companies.	Farmers in a remote southwest province of Yunnan. Potential users are about 1 million.
ES-d	A comprehensive aquaculture disease diagnosis expert system called Fish-Expert at the local level.	Knowledge engineer develops the complete expert systems without using expert system shell.	Ministry's Modern Precision Agriculture System Integration in China Agricultural University in Beijing	Expert system team members	Large farms in rural counties of Beijing. Potential users are about 700.
ES-e	A comprehensive aquaculture disease diagnosis expert system further locally modified based on Fish-Expert at the local level.	Using the expert system architecture of ES-d. Knowledge based is modified by local intermediary organisations for local applications.	Ministry's Modern Precision Agriculture System Integration in China Agricultural University in Beijing	A local agricultural college	Large fishing farms in rural counties in Tianjin city. Potential users are about 100 thousand.

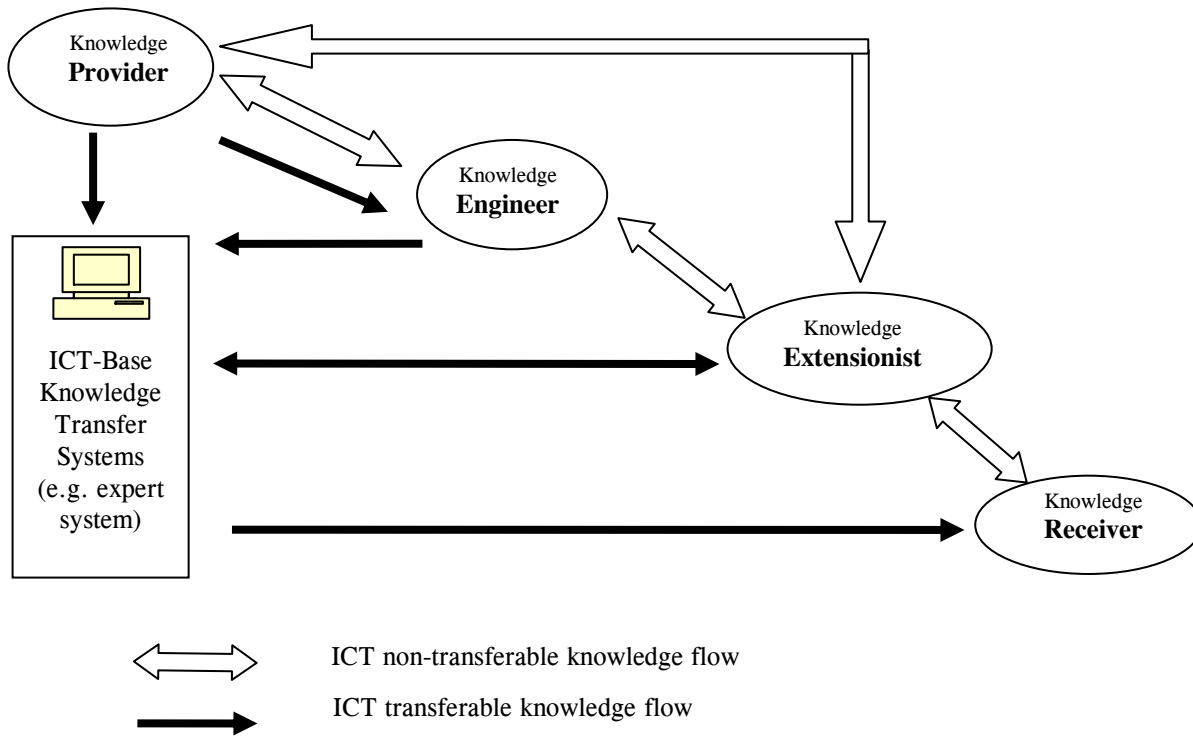


Figure 1. ICT based knowledge transfer process