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UNDERSTANDING THE PROCESS OF INNOVATION THROUGH THE THEORIES OF LEARNING AND COMMUNICATION

by

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A Report Submitted

In Partial Fulfilment of the Requirements

of the Degree of Master of Forestry

Faculty of Forestry

Lakehead University

1996

A CAUTION TO THE READER

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ABSTRACT

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Key Words: innovation, learning, communication, technology transfer, innovation diffusion, natural resource management.

Literature on learning, communication, psychology, sociology and related disciplines was reviewed. It was found that innovation is often incorrectly described in the literature as two separate processes. These are the processes of learning and communications, involved in invention and the spread of the invention, respectively. Research on learning and everyday life experiences show that learning and communications are closely interrelated. Invention involves learning and communication, and the spread of inventions also involves both processes. This information was used to develop a conceptual model of the process of innovation.

The process of innovation involves collaboration and learning by individuals within a social system, such as a work centre. The conceptual model, called the collaborative learning model, was used to describe the factors that influence innovation. Three major factors influence innovation. These factors are: 1) factors internal to the individual such as motivation, and learning experience and skill, 2) cultural factors such as the development of socially acceptable behaviour, and 3) factors related to the use of technology. Examples from natural resource management are used to describe the collaborative learning model and factors that affect innovation.

Innovation, while often desirable, may not occur, and at other times may result in unforseen negative consequences. The complexity of the process often makes innovation difficult to plan or carry out. The collaborative learning model and literature suggest that unforseen negative consequences are part of the innovation process. Unforseen negative consequences may occur due to the interdependences amoung technological, social, and environmental systems. Changes in one, usually the technological system, may result in unforseen changes in the social or environmental systems. The only way to reduce negative consequences of innovation is to continue innovating.

CONTENTS

	Page
ABSTRACT	iii
FIGURES	vii
ACKNOWLEDGEMENTS	ix
IMPORTANCE AND DILEMMAS OF INNOVATION	1
CONVENTIONAL VIEW OF INNOVATION SPREAD	3
What is Learning?	3
Learning to Create and Use New Ideas	5
What is Communication?	11
THE INNOVATION PROCESS	14
A Collaborative Learning Model of the Innovation Process	15
FACTORS INFLUENCING THE INNOVATION PROCESS	20
Factors Affecting Innovation at the Individual Level	21
Motivation	21
Implications of Motivation on Innovation	24

	Page
Learning and Innovation	27
Compatibility with Past Learning and Innovation	27
Learning Skill and Innovation	30
Social Aspects of the Innovation Process	33
Social Learning and Innovation	34
Group held Ideologies and Innovation	35
Social Organization	38
Organizational Characteristics and Innovation	38
Use of Authority in the Innovation Process	39
Organizational Types and Innovation	42
Innovation in For-Profit Organizations	42
Innovation in Public Agencies	45
Informal Organizations and Innovation	49
Technology and innovation	50
Technology and the innovation process	53
USING THE COLLABORATIVE LEARNING MODEL TO IMPROVE INNOVATION	56
The Innovation Process and Suggestions for Improving Innovation	56
Social Systems and Suggestions for Improving Innovation	58
Technological Systems and Suggestions for Improving Innovation	62

	Page
SUMMARY	64
LITERATURE CITED	67

FIGURES

Figure		Page
1	An important type of learning in the creation and use of new knowledge is the detection and correction of error	6
2	Four classes of error can be detected between the desired and actual outcomes of a person s action	8
3	Components of a simplified interpersonal communication system	12
4	The innovation process described by learning and collaboration by individuals in a social system	16
5	The three major factors affecting innovation	23
6	Factors affecting motivation	25
7	Factors affecting learning in an individual	28
8	Example of a complex innovation: a stand density diagram for red pine	32

Figure		Page
9	A group's tolerance for uncertainity, risk, and failure will affect innovation	36
10	Authority within social systems, such as workplaces, have the power to influence the process of innovation	40
11	Social systems may be grouped into organizational catagories	43
12	Factors of technological systems that affect innovation	54

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IMPORTANCE AND DILEMMAS OF INNOVATION

Many consider innovation important for the growth of industrial countries (Porter 1991, Brodtrick 1994, Dodds 1994), important for the welfare of developing countries (Warboys 1983), and necessary to reduce the possibility of human-caused environmental disasters (Maser 1994, Hanley 1994). Innovation is also important in forestry. Forestry is an important component of the economies of many industrialized and developing countries. For example, in 1991 exports of forest products from Canada, Sweden, Brazil, and India amounted to about 17, 10, 1.5 and 0.9 billion U.S. dollars respectively (Canadian Forest Service 1993a: 213). Further, innovation enabled pulp and paper producers in Canada to reduce their discharge of dioxins and furans between 1988 and 1993 by over 98% (Canadian Forest Service 1993b: 107). Innovation also allows free-enterprise forestry organizations to remain competitive in global markets, and government-run forestry agencies to operate effectively and efficiently.

If forestry is to be innovative, individuals involved in its practice must be able to make informed decisions on the use of new ideas, devices or processes. Enabling individuals to make informed decisions on innovations is not an easy or straightforward task. Desirable innovations with clearly positive results often do not happen (e.g., Rogers 1983, Schwartz 1992). Further, innovation can also have unforseen unpleasant consequences. For example, the introduction of technological innovation in forestry in Canada since the 1970's has resulted in higher productivity but also created fewer forestry-related jobs per unit of output (Canadian Forest Service 1993b: 74). If this trend continues, it may result in competitive firms but also in fewer people working in the forest industry sector.

We need to understand the process of innovation if we want to ensure people make informed

decisions on new ideas, devices or processes. Many disciplines describe the process of innovation, each from its own perspective. For example, the process of innovation is described in literature related to economics, education, sociology, psychology, and organizational development, to name a few. Literature from these and related disciplines is reviewed in this report. The results of the literature review are used to describe the innovation transfer and adoption process. Insights in the innovation process obtained from past research are used to describe factors that could affect the transfer of forestry innovations. Suggestions on how individuals and organizations involved in forestry can make informed decisions on innovations are also described.

CONVENTIONAL VIEW OF INNOVATION SPREAD

Wide use of an innovation requires two events to occur. First, it requires the creation of an invention. Invention is an active learning process that involves solving problems creatively, experimentation and study (Anon. 1986: 636). The process of learning occurs in the minds of individuals. If the invention is to be used widely, a second event must also occur: the invention must be made known and available to people who can use it. The innovation transfer phase of the process involves some form of communication through which the invention and its results are described to others.

Studies on the spread of innovations have considered invention as essentially a learning process, and the spread of invention as primarily a communication process (e.g., Rogers 1983: 34, Hobbs *et al.* 1993). But research on learning has shown that communication and learning are intimately linked (Cullingford 1990: 71, Bosworth and Hamilton 1994: 3). Therefore, to obtain a better understanding of the spread of innovation, invention must be considered as both learning and communication. Similarly, the spread of an invention should be considered within the context of both learning and communication. The following two sections describe the role of learning and communication in the process of innovation.

WHAT IS LEARNING?

Learning is an active process through which an individual can increase skill, knowledge or understanding. The process of learning occurs at both the individual and social levels. At the individual level, learning involves comprehension and transformation of one's experiences and past learning into new thoughts and actions (Kolb 1984). Individuals must be able to perceive an

experience through their senses, understand the experience, relate the experience to knowledge gained from past experiences, and use the resulting thoughts to create new knowledge and action. All experiences may not lead to an increase in skill, knowledge or understanding. One's experiences and thinking processes may be confounded by one's emotions, beliefs, inner needs, prejudices, and illogical thoughts (Adams 1986, Cullingford 1990: 6). Individuals tend to develop a pattern of perceiving and thinking that may force contradictory facts or experiences into one's established pattern of perceiving and thinking (Cullingford 1990:219). This suggests that the creation, acceptance and use of new ideas will not occur easily or quickly.

Recent research has shown that learning is a naturally social act (Holland and Kobasigawa 1980, Phares 1980, Bandura 1986, Leinhardt 1992, Gerlach 1994). Individual knowledge is shared and transformed within and among people. For example, a forest technician may seek the help of other technicians in deciding to retain or remove a tree in a tolerant hardwood stand being marked under the selection silvicultural system. The technicians can share their current knowledge and transform it to arrive at a decision. The process of seeking and using learning of other people is one example of the close links between communication and learning.

The social aspects of learning suggest that learning has rational, normative and emotional dimensions. Phares (1980) suggests that social learning theory implies that an experience leading to learning is not merely a set of physical stimuli such as light, colour or warmth. An experience also has meaning about relationships with other people. People are aware, though often unconsciously, of factual information, and also the perceived internal reasons, such as psychological or emotional reasons, for an action. For example, the suggestion of a woodlands manager may appear more persuasive to a logger working for the same company than the same suggestion made by a fellow logger. Here the higher status of the manager may cause the logger to heed the suggestion, whereas the information provided by a peer may be disregarded.

Learning has a definite utilitarian purpose (Phares 1980, Cullingford 1990: 206). An individual learns so that the individual may benefit from the new understanding gained. An individual may receive direct tangible benefits, such as greater comfort or convenience on using new knowledge. The individual may also use knowledge to obtain benefits from social relations, such as an increase in acceptance or recognition from other individuals. Social learning suggests that peer groups are sounding boards for ideas (Cullingford 1990: 127). Individuals can detect what others feel about holding certain attitudes on different subjects. The sounding board process plays an important role in how new ideas or relationships are accepted or discarded.

Learning to create and use new ideas

One type of learning, important in the creation and use of new ideas, is the detection and correction of error (Fig.1). This form of learning is described by Piaget (Forman 1980) and Argyris (1993). Error is any discrepancy between the intended and actual outcomes of an action. For example, a fishery biologist observes stocked lake trout are not reproducing in their new habitat. The biologist has detected a discrepancy between the actual and desired rate of reproduction. The biologist may then test several premises to detect what may be affecting the reproduction of the fish to correct the problem. Through the tests, the biologist increases knowledge and understanding of the possible factors that may contribute to the failure of the trout to reproduce.

According to Argyris (1993), this particular form of individual learning may begin with the detection of error. Brown (in litt., 27 February 1995) suggests four classes of errors are discernible between intended and actual outcomes of actions (Fig. 2). Fictionalized problems in forest regeneration illustrate the four classes of error.

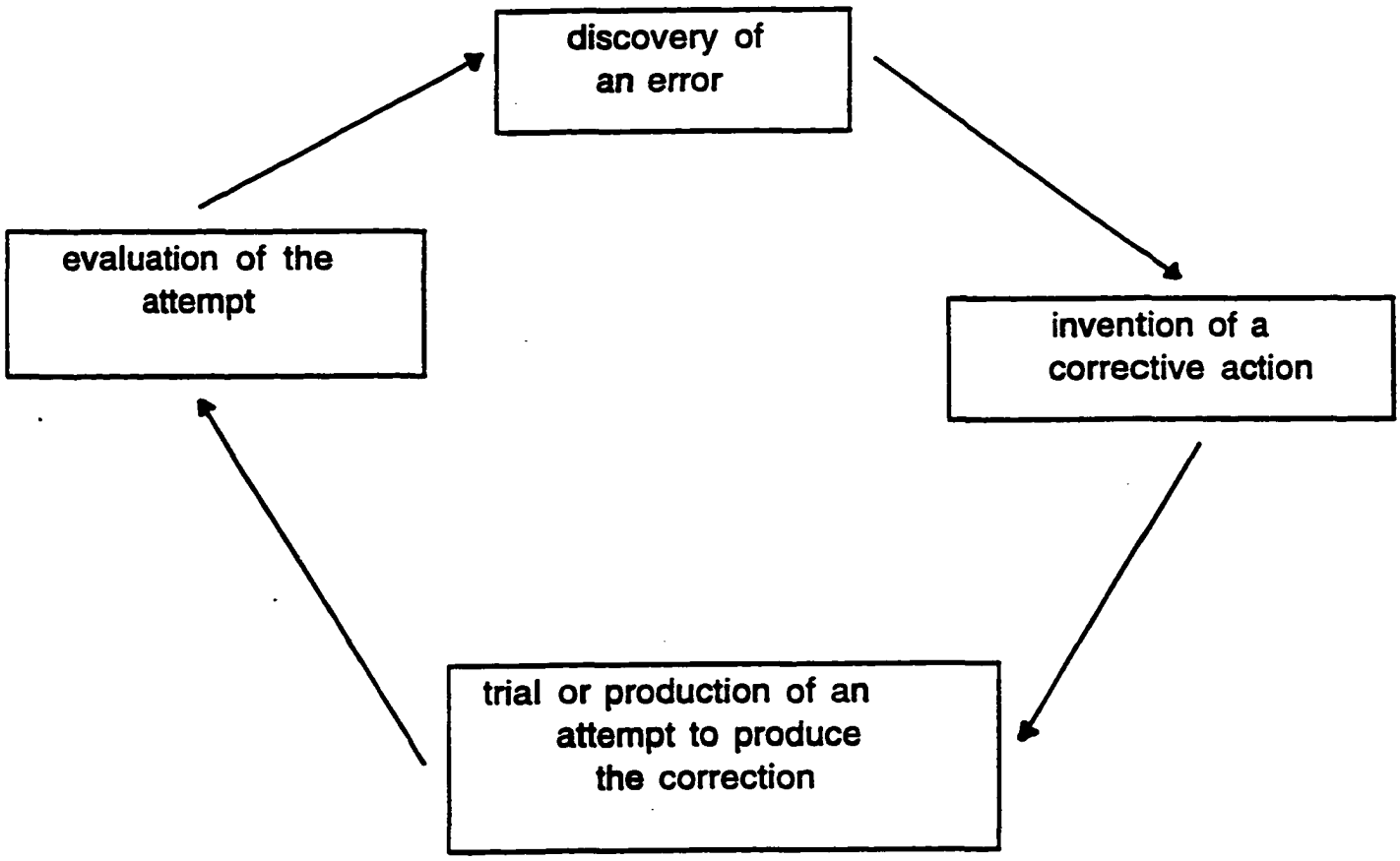

Figure 1. An important type of learning in the creation and use of new knowledge is the detection and correction of error (Argyris 1993)

The types of error possible are:

1) A contradiction between the *present* and the *present goal*: A forester discovers that the available planting stock is insufficient to regenerate areas available for planting this season. The discovery suggests a discrepancy between the perceived present (area available and suitable for planting) and the present goal (plant all suitable available areas).

2) An error in the *current method* used: A forest technician discovers that the method of calculating plantable spots is biased. The current method of determining plantable spots of areas available for planting will result in more seedlings being ordered from the nursery than can be planted. The discovery shows present efforts to close the gap between the perceived present (area available for planting) and the present goal (planting all suitable available area) is based upon faulty methods.

3) A contradiction between the *perceived present* and *perceived reality*: A forest company finds out that clearcutting and planting old growth forests is against the code of practice of some of its customers. The forest company must face a new reality that is substantially different from the present. The current harvest and regeneration practices were based upon the reality that a forest had to be regenerated, which the company diligently attempts. However, the new reality dictates other practices should also be used.

4) A discovery of a difference between the *current goal* and a *wise goal*: A forest company searching for ways to ensure a sustainable level of economic activity decides to change its goal of simply regenerating a forest to one that also maintains current levels of forest diversity. The company, aware of new information on the functioning of forests, has detected a difference in its current goal (regeneration) and a wiser goal, i.e., maintaining forest diversity.

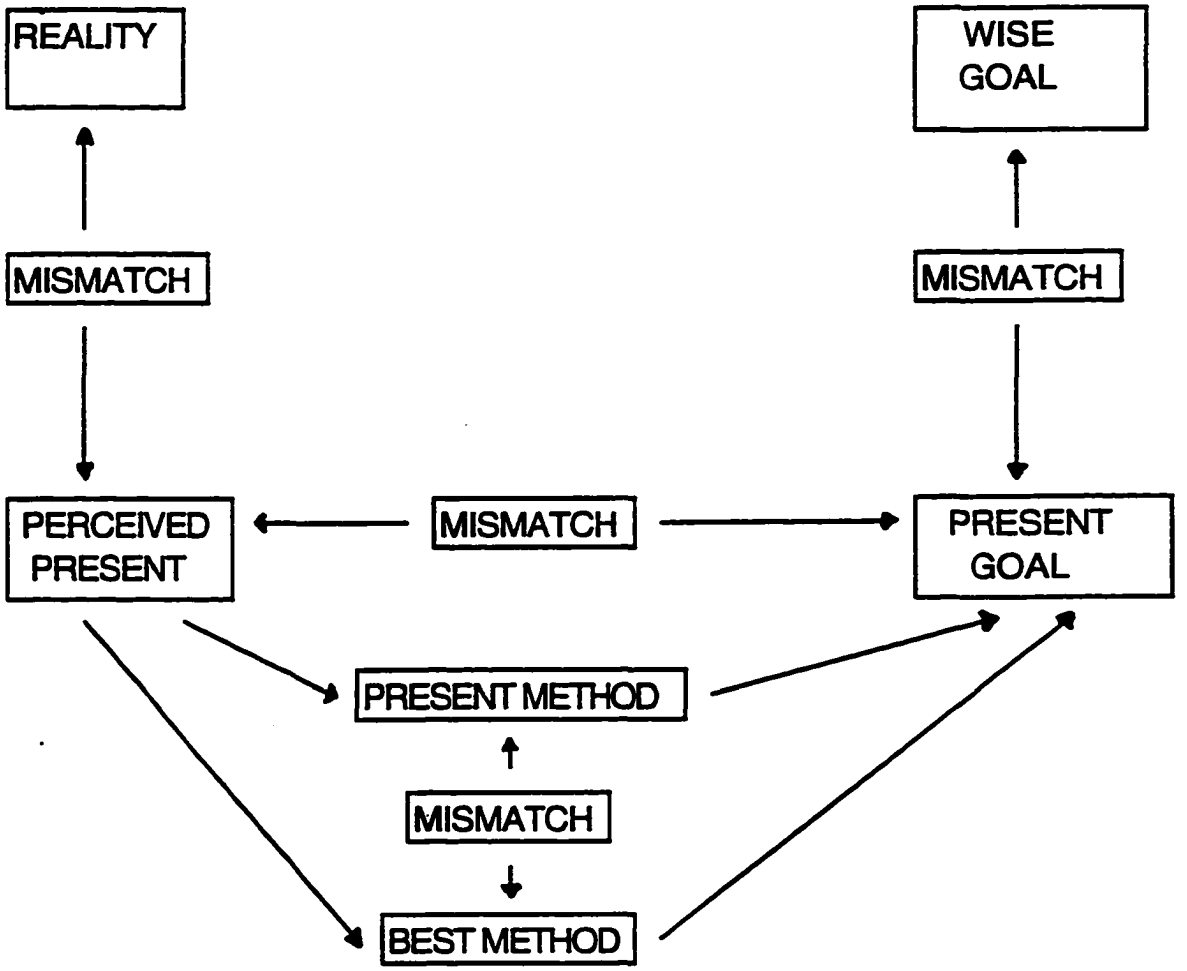

Figure 2. Four classes of error that can be detected between the desired and actual outcomes of a person's action.

The first two classes of error, (1) and (2), tend to identify routine problems. Routine problems are errors that fit into a problem type we have experienced in the past. For example, the individuals in error type (1) may have had an experience in the past where a desired quantity of an object such as eggs or money did not match the quantity available. Or the individual may have been told to plant all of the available area, and determined that he or she will be unable to fulfil this command. The individual can use his or her past experiences to help find a solution to the current problem of not having the desired number of tree seedlings. Routine problems are focused on how to do *something better*, not can I do a *better thing*. In the examples described in error type (1) and (2), the solutions will help improve tree planting. They do not ask if we should be planting trees, or doing something altogether different.

In routine problems the source of error is usually not in question, and the solution, derived from past experiences, is easy to state. This does not mean that the error may be easily solved. In the example described in error type (1) a discrepancy exists between the available planting stock and required planting stock. While the problem and its solution may be easy to state, there may be practical barriers to solving the problem, such as the unavailability of suitable nursery stock. Similarly, technical barriers, such as a lack of skill in statistics, may limit the use of a suitable solution to the problem described in the example for error type (2).

Routine problems can be detected by careful analysis of the information available. If the problem cannot be detected immediately, it may be determined by gathering and analyzing additional data. For example, in (1) above, additional field surveys may be needed to determine a more precise estimate or to confirm the need for additional planting stock.

The second two classes of error, described in error type (3) and (4), identify a different set of problems. Unlike routine problems, these problems question the norms of the social group. In

example (4), the forest company has recognized a problem with the way it perceives the world. It has identified that the problem lies not just with technical or rational aspects such as annual allowable cuts, but also with social, moral and ethical aspects of its endeavour. To solve the problem, a change is required in both the technical and rational aspects of its operation, and also the norms that govern how individuals in the company perceive and interact with the world around them.

Detecting and correcting errors that challenge the norms of a social group are usually much more difficult than detecting and correcting errors that occur within socially acceptable rules of behaviour. For example, finding and using a new method to calculate the number of plantable spots should be fairly easy. Calculating plantable spots is already an acceptable practice. It is considered useful to the regeneration effort, and mechanisms are in place to ensure it is done. Before a solution that challenges the norms of the social group can be used, the individuals in the group must first be convinced that the solution is desirable. The individuals in the group must then be assured the methods necessary to do it are in place. For example, in changing forest management goals from just regeneration to maintaining forest diversity, individuals in a group have to convince its other members that the new goal is desirable and also practical.

Detecting and correcting errors of the type described by error type (3) and (4) may result in searching for new ways of perceiving the world. These types of errors require people to explore their world in completely new ways. They require individuals to ask not "how do I do something better," but "is there something better to do?". In both examples (3) and (4), the forest company changes what it does and how it does it. In the routine problems described in (1) and (2), the individuals change only how they do things, not what they do.

The detection of error is a key aspect of invention. An individual who can detect error may start the

process of inventing a solution to the problem. Error detection is also a key factor in the spread of inventions, a fact often overlooked by innovation spread researchers. Before using new knowledge developed by someone else, an individual must be able to predict and feel comfortable with the consequences of using or not using the new knowledge. Any factors that influence the detection or prediction of error will affect the creation and spread of innovations. For example, if a forester is faced with having to adopt a new partial cutting system, he or she must be able to predict some of the consequences of using the partial cutting system to harvest and regenerate a particular forest cover type. The forester must feel comfortable that his or her employer, clients and forest stakeholders are prepared for the outcomes that may occur. Further, the forester must be assured that the ecological consequences are more positive than the current silvicultural system.

WHAT IS COMMUNICATION?

Communication is the transmission of information from one person to another so that it is satisfactorily received and understood. Communications involve a system. At a simple level the system may involve (a) a source with information to send, (b) a message, (c) a medium through which the message is transmitted, and (d) a receiver of the message (Fig. 3). Like learning, communication is a dynamic process, requiring the attention and action of the sender and receiver. Also like learning, it involves processing information through one's ideology of beliefs, values, attitudes, and one's innate sensory and cognitive skills (McCroskey and Wheeless 1976: 29).

The function of communicating is similar to that of learning. It enables people to improve their understanding, knowledge or skill by enabling individuals to tap into a larger collective knowledge set. Communicating, like learning, also serves a social function of maintaining and influencing social relationships. The similarities between the functional roles of communicating and learning

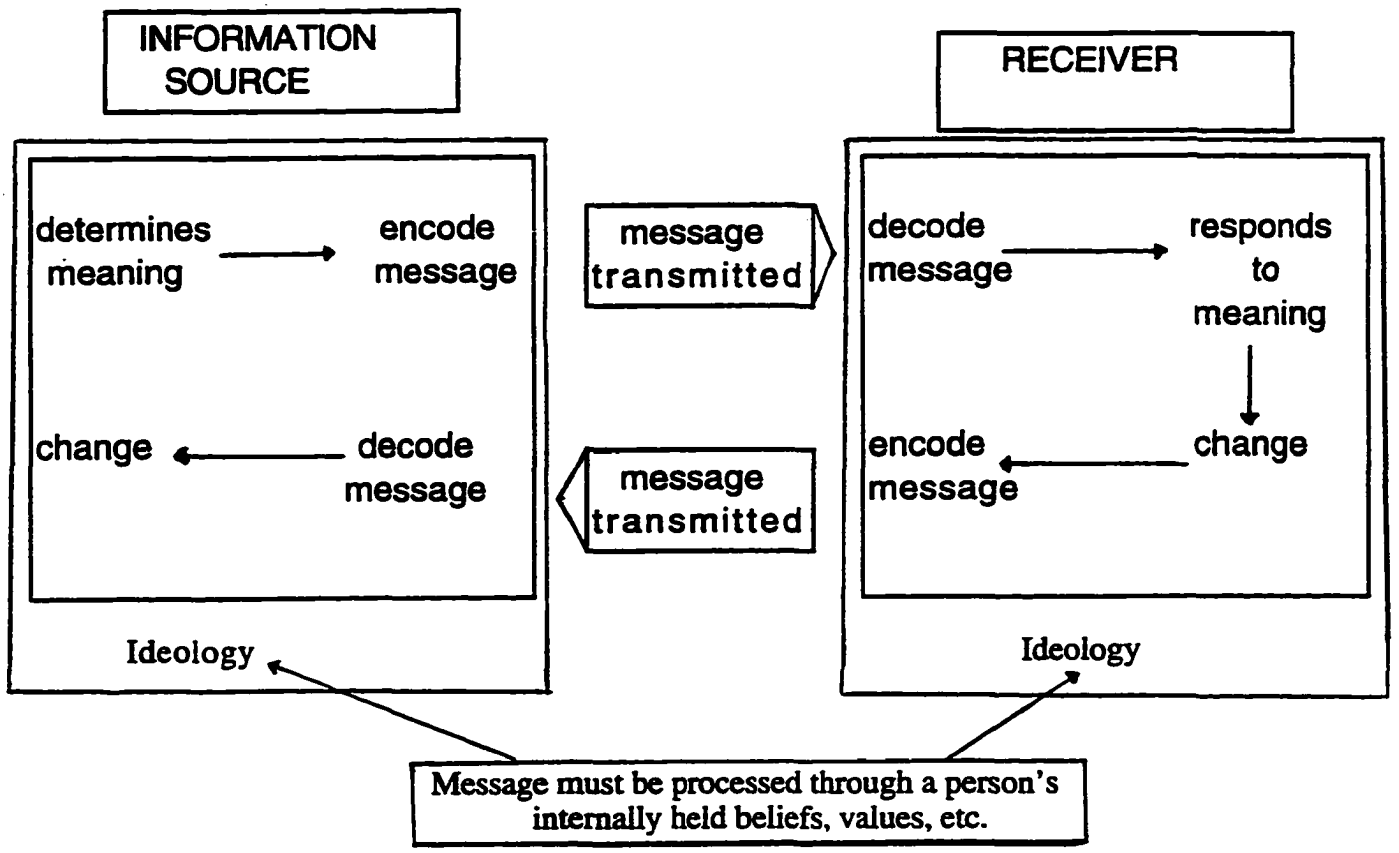

Figure 3. Components of a simplified interpersonal communication system (McCroskey and Wheeless 1976: 24).

illustrate the close relationship between the two processes.

Communicating is an important source of real and vicarious experience. For example, a forest technician can describe the site conditions to a forester who has not visited the forest stand. The forester's experience is real, a dialogue with the technician, and also vicarious: the forester obtains some sense of a site that he or she has not visited. An individual can use the experience obtained through communicating in his or her learning process. Information transmitted can consist of a mixture of information that the receiver may decode and understand. Communication can consist of information made up of facts, concepts, notations and also information on values, beliefs, and relationships. For example, the forest technician can describe the site as having "a deep sandy soil capable of growing jack pine." The dialogue provides factual information using codes (deep and sandy) that can be deciphered and understood by the receiver. The communication also consists of a belief statement (capable of growing jack pine) and an unspoken relationship message (the work relationship between two trained forestry workers).

Interpersonal communication, such as the dialogue between the forester and forest technician described above, provides the potential for interaction and mutual influence. Interpersonal communication has the potential of providing an individual with information that is conceptual, social and psychological. In the example in the paragraph above, the two individuals can question each other to obtain a thorough understanding of the issue being discussed. Mass communications lack the full potential for interaction and mutual influence and usually lack information people may need to fully understand the social implications of the message. Rogers (1983: 273) says that "mass media channels are primarily knowledge creators, whereas interpersonal networks are more important at persuading individuals to adopt or reject" an innovation. Individuals require more than factual information if they are to become informed and act. They also need information on the social implications of their potential actions such as adopting or rejecting an innovation.

THE INNOVATION PROCESS

The literature on innovation lacks complete descriptions of the innovation process. Most of the literature describes the innovation process after a solution to an error has been invented. For example, innovation diffusion research describes the process of how inventions spread in society. Innovation diffusion research is a term used to describe a class of communication research that attempts to describe how inventions spread among members of a social system such as woodlot owners in a county. It consists of a large body of literature, estimated at over 3,000 items (Rogers 1983). Innovation diffusion researchers such as Ryan and Gross (1943), Coleman *et al*. (1957) and Rogers (1983) have contributed greatly to our current understanding of the spread of inventions. They have shown that the spread of inventions is affected by social and rational factors. They have also shown that the spread of inventions is a result of awareness of new ideas and also the approval or convincing from other people held as opinion leaders by the adopters of the solution. Opinion leaders are individuals who lead in influencing other peoples' opinions about the use of an invention (Rogers 1983: 271). These studies are important as they provide empirical and verifiable results on the spread of inventions.

Case studies are another source of information on the process of innovation. Case studies provide anecdotal descriptions of a problem, invention of a solution, and the spread of the invention (e.g., Kiil *et al*..1986, Marx 1986, Cayford and Riley 1986). Other case studies provide an institutional model of innovation (e.g. Witter *et al.* 1982, Wheeler and Hehnen 1993). These studies describe the flow of new knowledge from basic research, through applied research, and prototype development, to mass production. Case studies have limited utility in understanding the innovation

process because solutions that were not adopted or used widely are not reported. They also assume that rational thought and awareness of the invention are the main factors in the success of the invention. For example, Cayford and Riley (1986) only describe examples of successful adoption of inventions developed at their research organization. They and Marx (1986) also assume that a planned approach of simply making potential adopters aware of new inventions from their research organizations will result in adoption of the new inventions.

To understand innovation better, a complete description of the innovation process is required. A complete model should describe the process leading up to identification of a problem, inventing a solution, trial or use of the solution, and the evaluation of the results of using the solution. Such a model can be developed using elements of learning and communication theory.

A COLLABORATIVE LEARNING MODEL OF THE INNOVATION PROCESS

Innovation involves both learning and communication. A simple innovation model can be described using Argyris' (1993) model of learning and linking it with communication (Fig. 4). The collaborative learning process described by this model suggests that an individual can complete the learning process by him or herself or with the assistance of others. Completion of the learning process by one individual means that only that individual benefits from his or her learning.Innovation cannot occur until others become aware of the new knowledge.

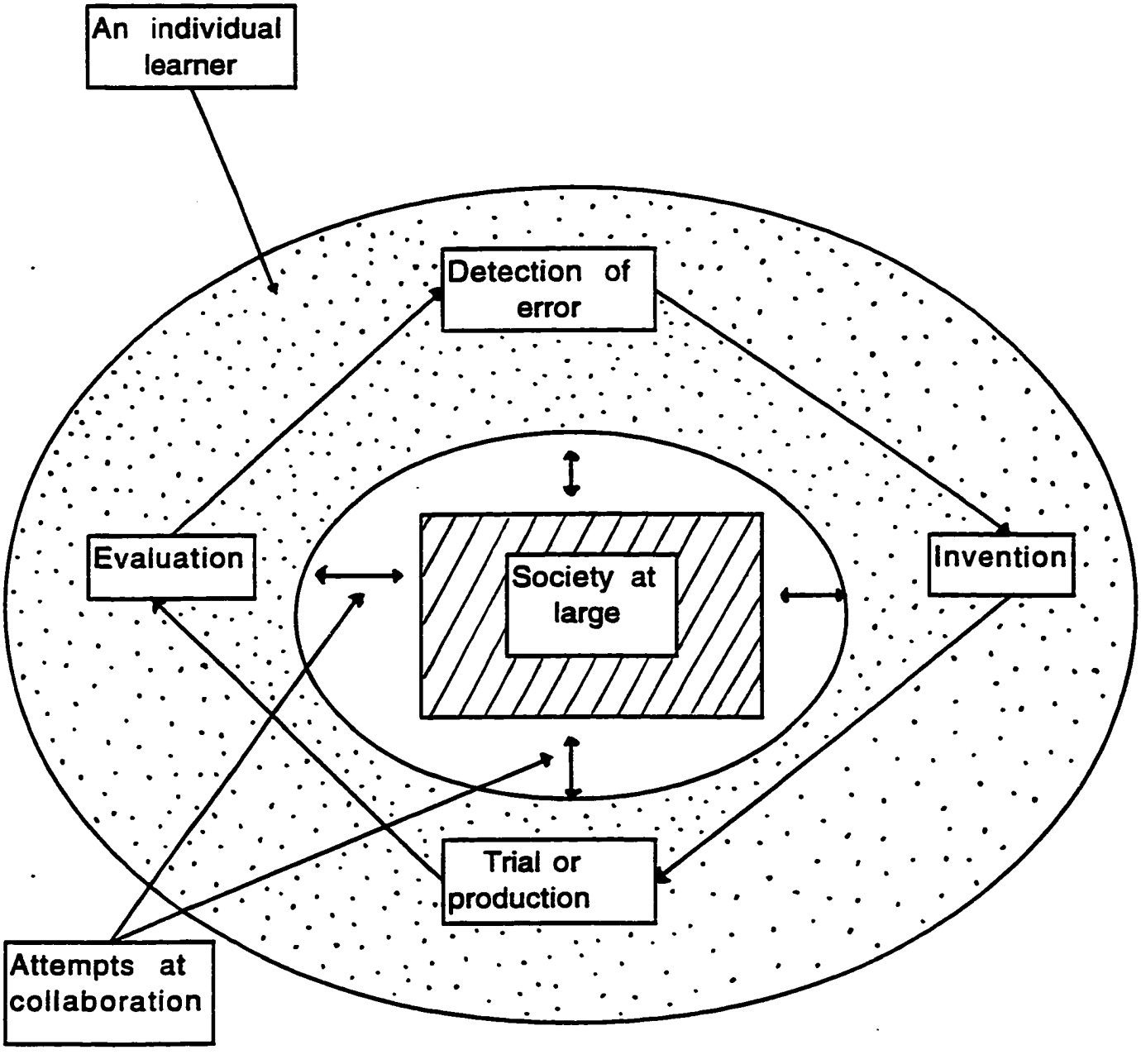

Figure 4. The innovation process described by learning and collaborating by individuals in a social system.

Innovation may commence with the discovery of error (Fig.4). An individual who detects an error may attempt to communicate his or her discovery to others. For example, a sampling method to determine the number of plantable spots in a planting chance is found to be biased. This information may be communicated to others that use the sampling method. It may also be sent to those that have specialized skills such as statisticians who may be able to solve the problem. The message transmitted may not be attended to or understood immediately. In fact it may be disregarded and forgotten. Only once the message is attended to and understood by the receivers will they commence learning. This is a form of innovation transfer because it involves creation, which in this case is the detection of a problem, transfer, and use of new knowledge.

The same individual, or another who received the message that an error has been detected, may invent a possible solution. This individual may also attempt to communicate the solution to others in the community. This will result in a second kind of innovation transfer. Such innovation transfer is probably the most common. Individuals, especially researchers, have an interest and ethic of informing their peers and others of their work. For example, an estimated 740 reports were published by Canadian forest researchers in 1993 (Baskerville 1994). Private and public agencies also have an interest in informing their owners, clients, customers or taxpayers of solutions that may improve their future profitability or perceived importance to society. For example, a university would want to ensure that research findings of its professors are widely known. Advertising its research achievements could result in improving the perceived worth of the university to potential students, employers of its graduates, alumni, donors, funding agencies, and staff.

Once a possible solution to an error is developed, it may be communicated to others and used to correct the error wherever it occurs. This is a third type of innovation transfer. It is at this stage of the innovation process that the benefits of the new idea are discovered or made known. Such

innovation transfer is important to individuals or groups that may benefit from the wide use of solutions in which they have a proprietary interest. For example, it is used in marketing, the spread of religious and political beliefs, and education. Each of these endeavours involves informing, convincing and getting others to use previously developed solutions. Many examples of this type of innovation transfer are described in the literature. Innovation diffusion researchers in particular have a large body of research on this aspect of the innovation process (Rogers 1983:375-377). Innovation diffusion research provides information on the factors that affect the spread of inventions such as adopter and non-adopter characteristics (e.g., Bertrand and South 1963, Ostlund 1974, Doolittle and Straka 1987, Haymond 1988, Hodges and Cubbage 1990). Innovation diffusion research also describes the characteristics of innovations and their rate of spread (e.g., Fliegel and Kivlin 1966, Olshavsky 1980).

Evaluation of the corrective action is the final stage in the innovation process. Individuals who have used or are affected by the invention may communicate with others. During this stage of the innovation process, the consequences of the corrective action are discovered. When further errors are discovered, the innovation process may start over.

The consequences of the use of innovations have not received much study. Rogers (1983: 337) estimates that only about 3% of the innovation diffusion studies have dealt with the consequences of innovations. He suggests that organizations sponsoring studies on the spread of innovations may have a pro-innovation bias. Many organizations, both private and public, can benefit from having their inventions used. They may sponsor studies that will help them in their goals. Also the study of consequences is often difficult to measure, requiring long study periods and specialized research methods.

The collaborative learning model describes the two major activities involved in innovation: learning

and collaboration. By collaborating with others an individual can influence his or her own learning, i.e., the ability to detect and correct errors. By doing so an individual is able to become more informed of current and potential new ways of behaving. The collaborative learning model may be used to describe the detection and correction of routine problems such as how to plant trees more efficiently. The model may also be used to understand more perplexing problems such as how or when we perceive events in a new way.

Collaboration and learning can be influenced by three major factors :

1) factors that influence learning within an individual,

2) factors that influence collaboration and learning within social systems, and

3) tools used by individuals to interact with their social and physical environments.

These factors and their influences on the process of innovation are described in following sections.

FACTORS INFLUENCING THE INNOVATION PROCESS

Innovation is a complex process. It involves many people, and can involve long periods of time and several interconnected processes. The collaborative learning model suggests that innovation involves processes that occur within an individual such as motivation, perception, cognition, and memorization. For example, a person must be motivated to try an invention if the innovation process is to continue beyond identifying an error and developing a possible solution. Understanding motivation and the other internal psychological processes will enable one to comprehend the innovation process more fully.

The collaborative learning model describes a social process. People learn within themselves and from others. This social process can be described by findings from sociology research, particularly from social learning (Bandura 1986) and innovation diffusion (Rogers 1983). Social learning and innovation diffusion suggest that people learn through observation and obtaining feedback from other people on the implications of new behaviour. Understanding group processes that influence learning and communication will improve our understanding of the innovation process.

Individuals interact with other people in small groups and in large groups. These interactions and factors that influence the innovation process may be derived from organizational and political science concepts. For example, large work groups are organized into distinct categories such as administrative, research and marketing units. The ability of these groups to interact, question, and collaborate will affect their capability to innovate.

Finally, people may interact directly with their physical environment and others or they may do so with technology. Technology allows people to expand their physical and mental abilities. By

expanding our sensory ability, such as with a microscope, technology enables us to become aware of events we would not be able to perceive otherwise. As we expand our ability to experience, we expand our ability to detect and correct errors, which in turn affects innovation. Today technology has become a major force in innovation as it improves our ability to learn and apply our learning.

Each of the major categories of factors (Fig. 5) influencing the collaborative learning model need to be explored in greater detail. This will foster an understanding of how the collaborative learning model functions and how the process of innovation may be influenced.

FACTORS AFFECTING INNOVATION AT THE INDIVIDUAL LEVEL

There are many psychological processes that influence learning and communication in an individual. For innovation, the most relevant processes are motivation and learning (Figure 5). Motivation describes the internal reasons an individual may attempt to innovate. Learning, with communication and thinking, describe the process of innovation within a person. Through learning an individual can increase his or her understanding of the world he or she perceives. The individual may then use the increased understanding to make an informed decision in detecting and correcting errors.

Motivation

Casual observation of individual behaviour in the innovation process shows that there is a great deal of variability in how people respond to the same stimulus. For example, how would a forester react when asked to try out a new piece of site preparation equipment? Would the forester reject the request right away, delay making a decision, or try to accommodate the request immediately? To understand the reasons for the observed variability in actions chosen, we need to consider the

motives that stimulate and guide behaviour toward a particular goal (Fig. 5). Studies in motivation can help one understand some of the variability in behaviour observable in an individual and between individuals.

Motivation is considered an internal process that initiates and directs behaviour in people (Reeve 1992:5). A stimulus, such as witnessing an event or an internal thought, is mediated by internal motives and result in the behaviour observed. Motivation theories describe motivation as a dynamic process, i.e., motivational states are in constant states of rise or decline. Changes in the strength of motives can be observed as a change in behaviour. Consider a forest technician writing a report indoors. The technician notices a bright sunny day outside. Over the day the technician may decide to put aside the report and inspect a logging operation. The technician may have changed his or her actions because of changes in expectancies in his or her performance and emotional outcomes. The warm sunny weather may cause the technician to reason that it would be more effective to work in the field than in the office. Also past pleasant experiences with similar weather may lead the technician to expect to obtain greater personal satisfaction by working in the field than indoors.

The process of motivation is complex. The complexity can be readily discerned by thinking of the number of possible actions one may take in response to a stimulus such as an upcoming holiday long weekend. Many theories have been described to explain why people do what they do (Reeve 1992). Any one theory can only partly describe motivation. Further, there is no consensus on how the various theories may be synthesized into a more robust theory of motivation. However, some ideas of the various theories on motivation can provide useful information on factors that may affect the innovation process.

Individuals are generally motivated consciously or unconsciously to choose actions that result in pleasant experiences and avoid actions that result in unpleasant experiences. For example, incentive

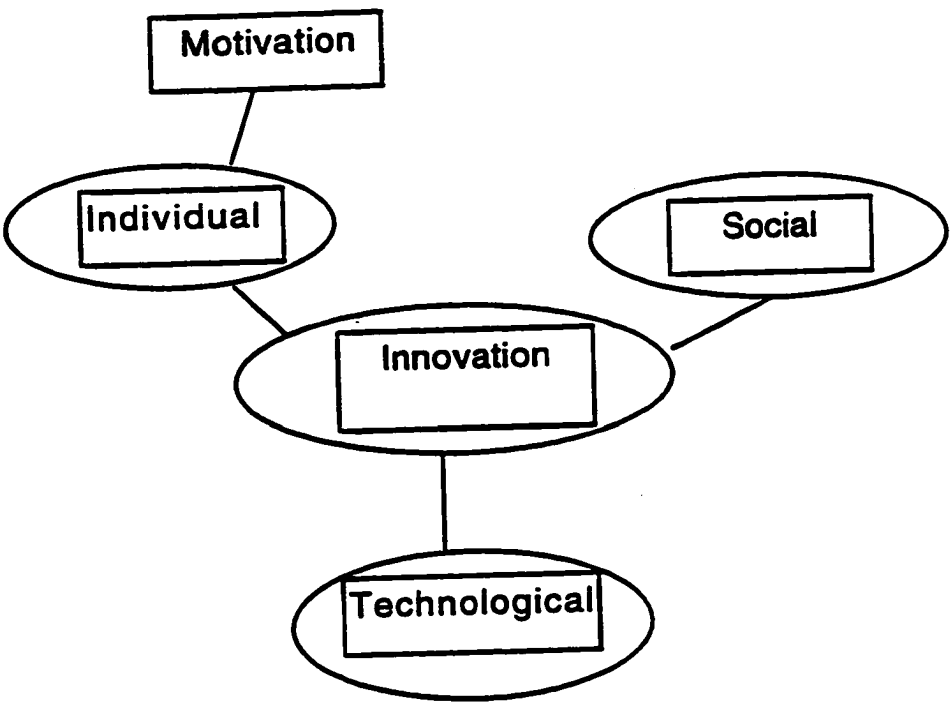

Figure 5. The three major factors affecting innovation. Motivation is an example of an important factor affecting innovation in an individual.

theories of motivation describe why individuals may choose a certain action if a reward is expected. Other theories also predict that individuals will choose actions that lead to pleasant experiences. Drive, arousal, opponent-process, attribution, self-efficacy, affiliation, and achievement theories of motivation all hinge upon the premise that an individual chooses an action that directly or indirectly is expected to result in a pleasant experience or avoidance of unpleasant experiences (Spear *et al.* 1988: 467-545). Similarly, Reeve (1992) describes physiological, extrinsic, intrinsic, cognitive, expectancy, and social motivations that suggest people will choose actions expected to result in pleasant experiences or avoidance of unpleasant experiences.

Implications of Motivation on Innovation

Motivation theory suggests that innovation for its own sake would not be favoured. Innovation involves change, grappling with the unknown, the potential of failure, and other consequences that increase the likelihood of an unpleasant experience. To innovate, an individual must be convinced, consciously or unconsciously, that the new action has some advantage over previous actions in leading to a pleasant experience.

Motivation theory suggests two major reasons an individual may want to innovate, that is, to want change:

- internal dissatisfaction with the present situation, and
- external forces causing dissatisfaction with the present.

In both cases an individual or group must believe that the likelihood of an opportunity to increase their satisfaction is high. Under this belief an individual or group should be more likely to make or seek changes (Fig.6).

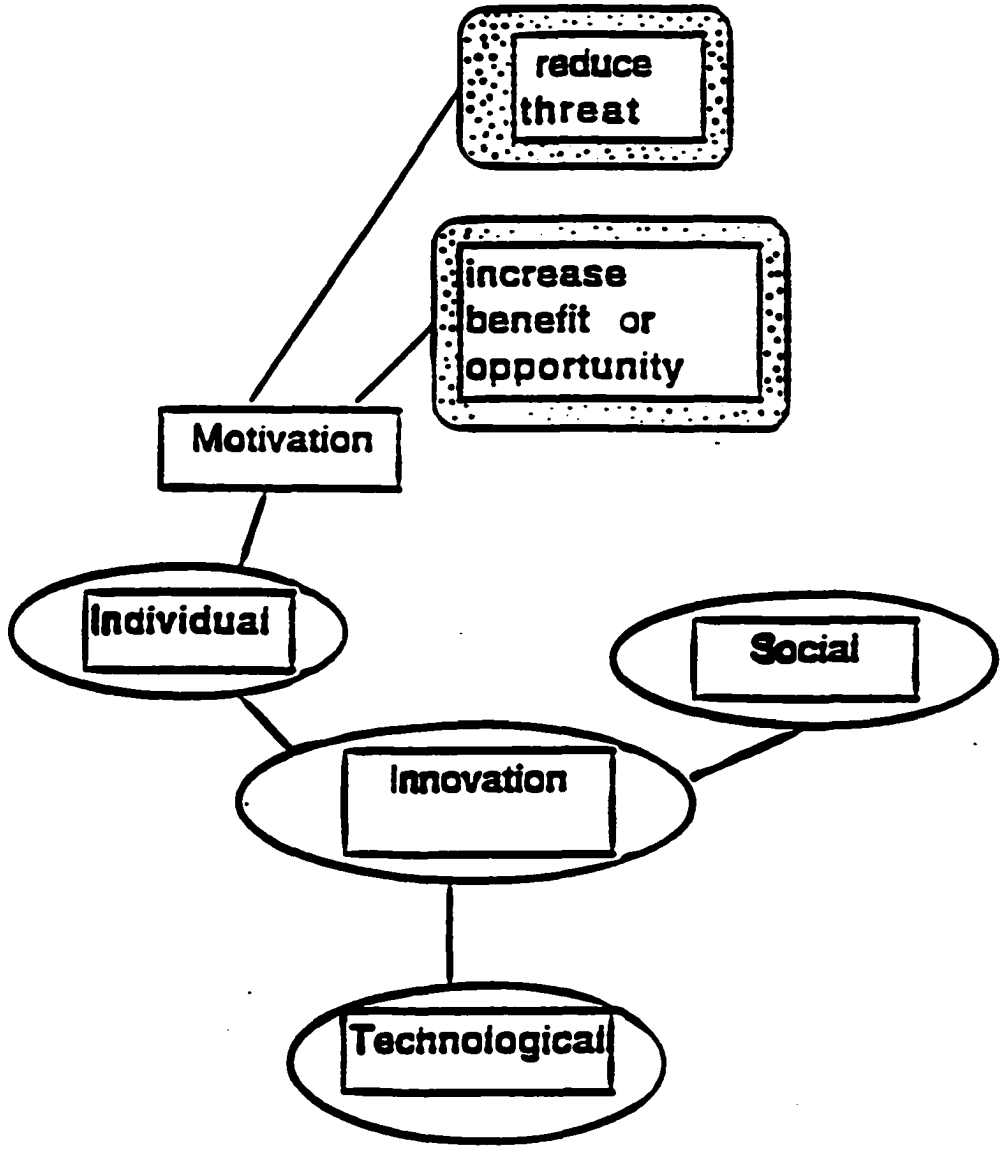

Figure 6. Factors affecting motivation. These factors increase the possibility of an individual innovating.

Research on the spread of inventions by innovation diffusion researchers supports motivation theory. Their work suggests that change will usually occur if an individual or group perceives an advantage in adopting an invention. Innovation diffusion researchers have shown that the perceived relative advantage of a new idea over an old idea is an important factor affecting the spread of inventions by potential adopters (Rogers 1983: 213-218). Relative advantages of innovations are both measurable, such as increased productivity, and also intangible, such as increased social acceptance or status. The perceived relative advantage leads the potential adopter to believe that adopting the innovation will likely lead to more satisfaction.

Motivation theories suggest that motivations, other than innate instinctual motives, can be changed by learning. For example, cognitive theories of motivation propose that individuals learn that certain behaviour lead to specific goals (Reeve 1992:175-178). Consider an individual who has learned through previous experiences that a certain action may result in loss of recognition by one's peers. Consciously or unconsciously this knowledge may motivate the individual to behave in new ways that are more likely to meet their approval. If motivations can be changed by learning and communicating, people have a great opportunity to use learning and communicating to improve the innovation process.

Motivated behaviour is affected by the same barriers that limit learning. Individuals are affected by learned impediments and defensive behaviour to rational thought such as biases and phobias (Adams 1986). For example, an individual may unconsciously only seek information that favours his or her existing beliefs. Such behaviour limits the information an individual may use in his or her cognitive processes and may make it more difficult for the individual to detect and correct errors. Individuals may also be limited in making rational decisions by their lack of learning. Learning affects how individuals perceive, process stimuli into useful information, and express themselves (Adams 1986). A limited ability to perceive information will influence how well an

individual can detect error and perceive solutions.

Also people may be more motivated internally to innovate and support innovation if they can benefit from it. The benefits may be tangible such as a pay bonus, psychological such as a greater sense of personal effectiveness, or social such a perceived increase in status or acceptance within a group.

Learning and Innovation

Due to the close relationship between learning and thinking, these processes are considered as the being the same. The following sections describe aspects of learning within an individual. Implied are the various mental processes necessary for an experience to be converted into thoughts and behaviour.

Compatibility with Past Learning and Innovation

Improving understanding involves the use of past learning to create, understand and transform new knowledge or experience (Leinhardt 1992, Gerlach 1994). The use of prior knowledge means that learning is an incremental process, but not a simple mechanical process of accumulation (Forman 1980). An individual may use new information to cause a major transformation of prior knowledge (Fig. 7). For example, a forester after completing some university courses in sociology may understand forest management planning and administration in a fundamentally new way.

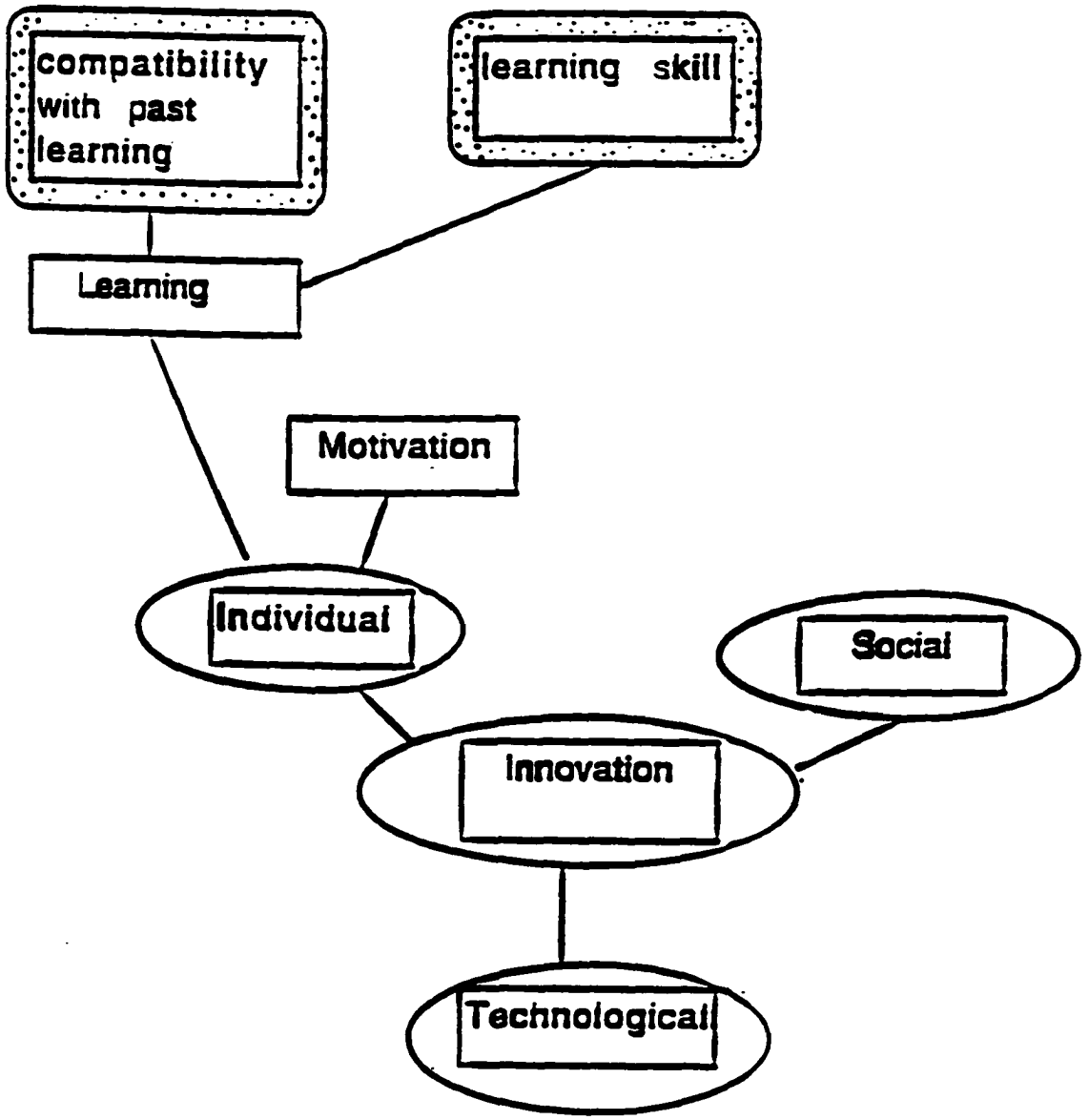

Figure 7. Factors affecting learning in an individual. These factors in turn affects an individual's ability to innovate

According to learning theory, people should understand a new experience more quickly if the new experience is compatible with past learning. Operant learning, insight learning, and observational learning theories all suggest that past learning plays a critical part in learning from new experiences (Spear *et al.* 1988:254-279). When a person is confronted with a problem they have successfully overcome before, the individual may have an easier time solving the new occurrence. Similarly, when an individual is aware of an invention that is similar to existing values, needs, or past experiences, there is a higher chance of the invention being used particularly if there is a relative advantage to be gained (Miner 1986, Haymond 1988, Hodges and Cubbage 1990).

Kolb (1984: 64-67) describes different styles of learning that individuals develop because of their individual experiences, innate sensory and cognitive skills, and demands of their current environment. For example, a soil scientist working in a university may develop strong skills in abstract concepts due to training and demands of the job. A park naturalist on the other hand may develop robust observational skills. These factors lead each person to develop a learning style that improves the chances of success for each individual.

Other aspects of learning may also become structured. Individuals can detect patterns in their environment because of their many experiences and use them to develop an ideology of beliefs, values, attitudes, biases, etc. The ideology becomes a framework through which an individual will usually perceive actions and experiences (Cullingford 1990: 111). This means that the experience will be less intense and a person's habits more constant. The benefit is a quick and efficient response to events, particularly events that are similar to past experiences. Unfortunately, one's ideology also makes it more difficult to detect and transform new information within an experience and therefore can reduce learning and innovation. For example, stereotyping, a learned behaviour, enables people to make sense of incomplete data (Adams 1986: 13-21). Adams also says that stereotyping may limit our ability to perceive.

A person who wants to detect error needs to be aware of the assumptions that form his or her ideology. Awareness and questioning of the beliefs, values, biases, and attitudes used to screen one's experiences will lead to greater self-awareness of the potential for pleasant or unpleasant experiences. Awareness of one's internal beliefs, values, biases, and attitudes can lead to a greater understanding of the incompleteness of one's knowledge. A desire to increase one's understanding may result in a person becoming internally motivated to be more knowledgeable.

Learning Skill and Innovation

The easier a person can understand a new experience, the more likely an appropriate decision in the innovation process may be made (Figure 7). An experience may be easier to understand if:

- the individual is a skilled learner, or
- the experience is inherently easy to understand.

Skilled learners would be more likely to be able to transform new experiences into usable information. A skilled learner may have a large repertoire of past learning to draw from. A large body of learning by itself is not sufficient to make a person a skilled learner. A skilled learner must also be willing to test his or her ideologic assumptions. However, only having a willingness to test one's assumptions will not lead to learning. An individual also needs the requisite information or methods to learn. So a skilled learner must be willing to test assumptions and have the information required to make correct decisions.

A skill may be developed through training and experience. Training enables an individual to learn from others who have achieved some level of expertise in a particular area of human endeavour. Experience provides an individual with opportunities to become aware and explore the

relationships between a particular behaviour and its consequences.

Studies on the spread of inventions by researchers of innovation diffusion agree that individuals with access to or with a higher level of learning may be more willing to innovate than less skilled learners (Rogers 1983: 82, Doolittle and Straka 1987, Royer 1987, Haymond 1988). In these studies, learning skill is implied from the level of formal education completed. Level of formal training may be one aspect of a skilled learner. It may suggest that individuals with more complex and advanced training have a higher ability to learn. The higher level of learning may enable them to make quicker decisions about adopting new inventions.

Complex experiences, or experiences that require complex transformation of thoughts, are less likely to be understood. An individual faced with a complex task is less likely to make a well-considered decision. Innovation requiring complex learning may be expected to be slow and difficult. Processes that help in simplifying the determination of errors, use of inventions, or consequences of new knowledge will assist the innovation process.

Innovation diffusion researchers show that inventions perceived as complex usually have slower rates of adoption than inventions perceived as simple (Olshavsky 1980, Rogers 1983: 230-231). For example, a stand density diagram is a complex figure with many lines describing predicted relationships between stand density, tree volume, height, diameter, inter-tree competition and mortality (Fig. 8). These diagrams may be perceived as complex, reducing the rate of their adoption by potential users. Implied in the adoption behaviour is the level of learning an individual may have to undertake before using an invention. Simpler inventions are easier to understand as

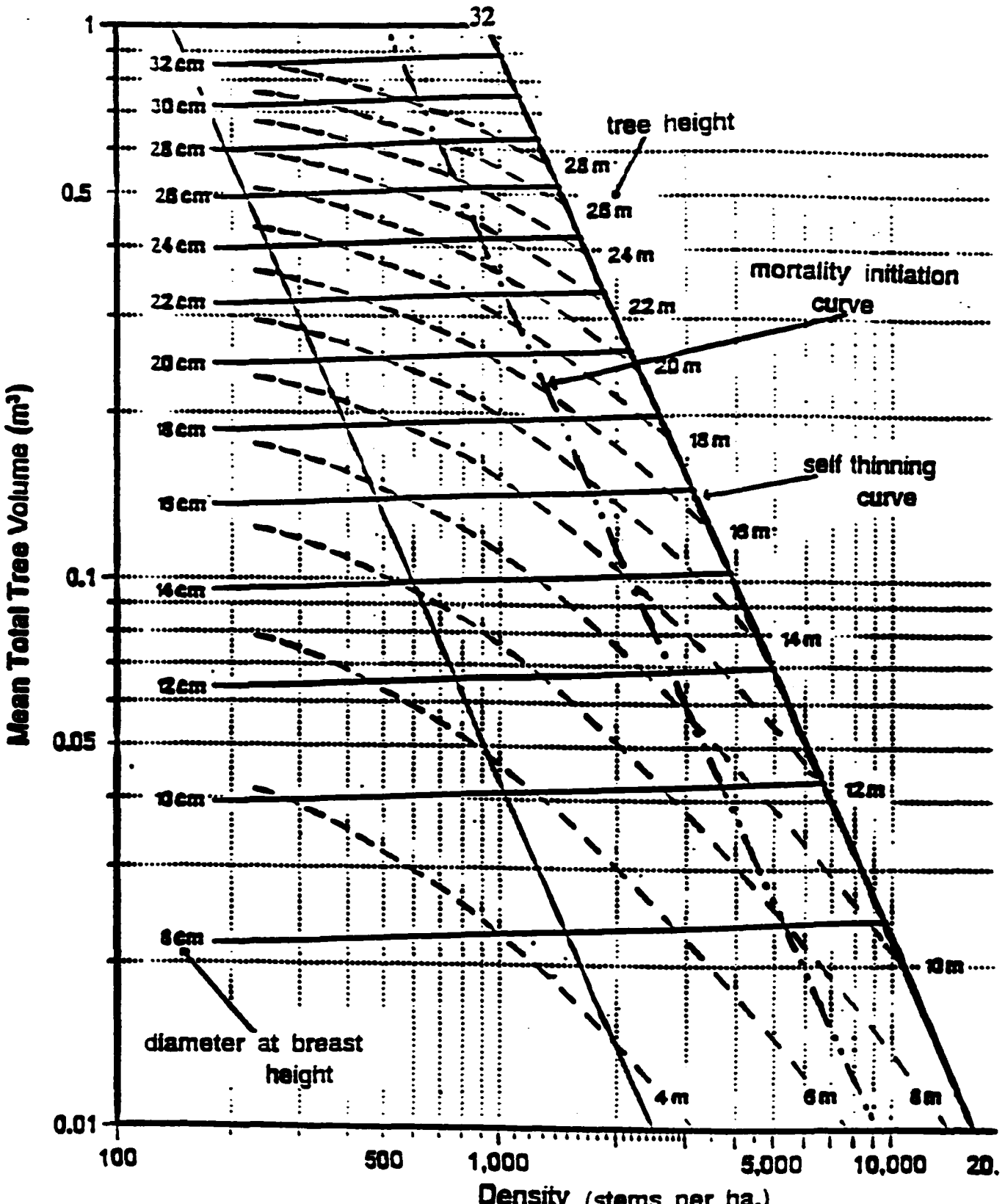

Figure 8. Example of a complex innovation: a stand density diagram for red pine (Smith and Woods 1995)

are their consequences. These attributes make it easier for people to quickly arrive at an informed decision. However, some people may resist or reject simple innovations, particularly if their past learning suggests that a complex solution is required to solve the error (Olshavsky 1980). For example, people believe that ecosystems are complex, and ensuring ecosystem sustainability will require complex solutions. Simple tools or methods developed to assist in sustainable management of ecosystems may be rejected as inappropriate for the perceived task.

SOCIAL ASPECTS OF THE INNOVATION PROCESS

Innovation is inherently a social process. For its occurrence people must collaborate and share information. Recent research in learning has described the social aspects of learning (Leinhardt 1992). People learn from one another when they interact, talk or exert influence on each other. Social learning (Bandura 1986) or observational learning (Holland and Kobasigawa 1980) theories provide useful insights into the innovation process. They are based upon the premise that people are influenced by their need to belong, be accepted, to achieve and be recognized, and to influence others (Spears 1989: 525-533, Reeve 1992: 285-307). These are strong social factors that may influence innovation behaviour.

Individuals cooperate in many different groups ranging from small to large. To cooperate effectively as large or medium-sized groups, which could be from tens to hundreds of individuals, people often organize themselves into functional groups or bureaucracies. For example a manufacturing work centre, such as a pulp and paper factory, may have functional groups. These functional groups may include categories such as manufacturing, sales, administration and research. The organization of people into functional groups influences communications and learning and therefore affects innovation. Concepts of organizational theory provide some insight into how innovation may be affected by bureaucracies.

Social learning and innovation

People have two reasons for belonging to groups: they can accomplish tasks more effectively, and they satisfy their socio-emotional needs of acceptance and recognition (Weber 1992: 177). To accomplish tasks people need technical information, such as how to operate a piece of equipment. They also need information on the social aspects of the use of equipment. Social learning, unlike individual learning, provides both types of information. It enables people to learn about technical aspects and the real and perceived impacts of the experience on the social recognition and acceptance.

The need for a variety of types of information is suggested in the responses found in a survey of forest managers in Ontario done by the Canadian Forest Service (Jaaskelainen 1991). This survey suggests that forest managers favour information transfer methods that provide them with a diverse set of information types in settings that are comparable to their work conditions. Field visits, demonstrations and workshops were respectively rated as first, second and third most useful to forest managers. Each of these information transfer methods involves interaction with people. Managers can discuss and share their opinions often in an informal setting on the technical, social and individually held attitudes at these types of information transfer settings. Information transfer methods such as tele-conferencing and poster sessions were rated as not useful by forest managers. These information transfer methods are useful for the transfer of technical information, but they limit the opportunity for the managers to obtain information on the social aspects of the work presented.

Group-held Ideologies and Innovation

Social learning is a rich source of information on cultural, moral and ethical issues (Holland and Kobasigawa 1980, Bandura 1986). It enables people to find out how others in their social group interpret issues in the context of their everyday living. This type of information is critical in the development of attitudes, beliefs, biases, prejudices and values that collectively may be called an ideology. Social learning is, therefore, an important form of learning in the development of one's ideology.

Individuals in groups may develop and hold common ideologies that can result in or influence social norms. Ideologies can affect the perception and mental processing of experiences (Adams 1986). Ideologies may also control the expression of acceptable behaviour by individuals in a social group. For example, individuals in an environmental group may hold similar values and beliefs. These values and beliefs in turn will affect the range and type of acceptable behaviour displayed by members of the group.

Some ideologies may favour innovation while others may reduce the potential for innovation. Ideologies that favour or tolerate risk, failure or uncertainty should favour innovation (Fig. 9). Innovation involves risk. The outcomes are not always assured; there may be negative outcomes or failures. Similarly, innovation should be favoured by ideologies that allow people to test the assumptions that form the belief and value system of the group.

Ideologies that may limit innovation are those that result in behaviour with a low tolerance for curiosity, failure and uncertainty. Such behaviour is judgemental, dismissive or hostile. People will sense the disapproval that these types of behaviour convey and refrain from innovation. Some groups, such as scientists, have attempted to limit the effect of such factors by seeking peer

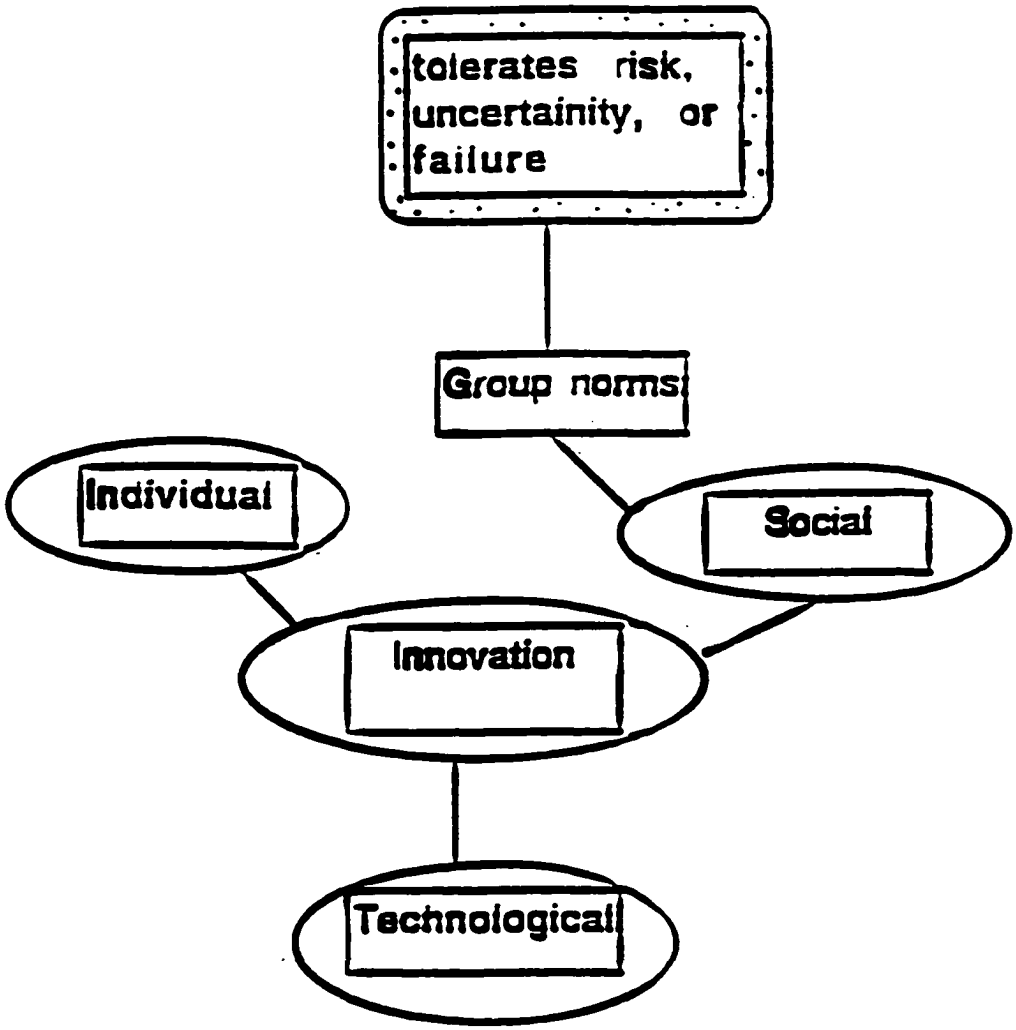

Figure 9. A group's tolerance for uncertainity, risk, and failure will affect innovation.

approval and recognition on objective measures of their work rather than broad social approval. For example, research results need to be verifiable to be accepted by other researchers. Social acceptance of the research may be debated by the researchers and others but it will usually not serve as the only reason to reject the work.

Groups wanting to be innovative have to ensure that people experience and are aware of the benefits they can accrue through innovation. An innovative group should protect and recognize people that are curious, invent new knowledge, try new ideas and evaluate the results of using inventions. Individuals need to be protected from the tendency of others to discourage innovation and the changes due to the perceived potential of negative experiences. There are many examples of successful invention in places where people are protected or hidden from others. Peters and Waterman (1984: 211-212) describe "skunk works" where many inventions have been developed. Skunk works are small groups of people using surplus resources to work on problems without sanction of others. Skunk works may exist in groups that have excess resources for use without formal approval of others in the group. Excess resources such as money, equipment or people have been found to be related to the early adoption of inventions (Mohr 1969, Perry and Danziger 1980).

Occasionally an individual may detect or attempt to correct an error that opposes a group-held belief. Such individuals, rather than hiding from the group, may confront it. These individuals stubbornly champion their points of view.

Champions may be perceived as a leader by supporters of the new ideas. They may serve as the symbolic identity of the new idea, and serve an important role in maintaining their supporters. For example, a champion was required in the commercialization of Taxol (Wheeler and Hehnen 1993). Taxol is a chemotherapeutic agent derived from the yew tree (genus *Taxus*) for the treatment of

ovarian cancer. The champion here had to ensure that the project secured sufficient resources and support to make it to commercialization by out-competing other ideas.

The type of change promoted by the champion may be positive or detrimental. Champions may base their new idea on limited or erroneous information and by the force of their character, circumstance, or other reason receive support from others. For example, the Ontario tube, a plastic container for growing and out-planting seedlings in the 1960's had its champions (Heeney 1981). However, the invention was based upon erroneous and limited information. The roots of seedlings were unable to egress through or around the plastic container, resulting in high plantation failure.

Social Organization

People may collaborate on common goals as small or large groups. The efficiency of large groups can be increased when the large group is structured into smaller groups. Each of the smaller groups is responsible for certain aspects of tasks that lead to the successful attainment of the common goal. Economic activity and governance of society are usually organized formally. These agencies, such as companies and government departments, each have their own goals, and various specialized people or groups of people assigned specific tasks.

Organizational Characteristics and Innovation

Formal organizations such as companies and government agencies have certain characteristics. Hodson and Sullivan (1995: 105) describe them as differentiation, integration, and authority. Differentiation describes how various activities are divided and assigned to different groups of people within the organization such as manufacturing and sales. Integration is the coordination of the various separate tasks so that the common goal may be met. Authority is the characteristic that

describes how control, responsibility, and duties are shared within an organization.

Collaborative learning is affected by the ability of individuals within an organization to communicate and share knowledge of errors, inventions, or the use of new ideas. The official division and linking of organizations into departments will affect both formal and informal communications. Official messages sent by the members of an organization will be routed through specific channels. Similarly, the opportunity for different individuals to meet informally will be dictated to some extent by the structure of the organization. For example, the sales force may be located in a main office away from the manufacturing plant, limiting the opportunity for members of the two groups to meet.

Authority in organizations is formal and informal. Formal authority may be found in written policies and procedures that describe the power and responsibility of individuals. Informal authority exists in the norms, beliefs, biases, and attitudes that develop within an organization. Just as individuals have their ideologies, people in organizations may develop common ideologies. These ideologies may be used consciously and unconsciously within the organization. Organizational ideologies serve the same purpose as individual ideologies. They allow people to behave consistently and efficiently in familiar tasks. They also reduce the ability of people to discern new information, find errors, or use new knowledge.

Use of Authority in the Innovation Process

Individuals or groups that have authority over others may use their power to influence the innovation process, such as by trying to promote the use of certain new ideas (Figure 10). For example, a government may legislate foresters to write pre-harvest prescriptions, or a company may decide to automate certain processes in its manufacturing process. Individuals within the

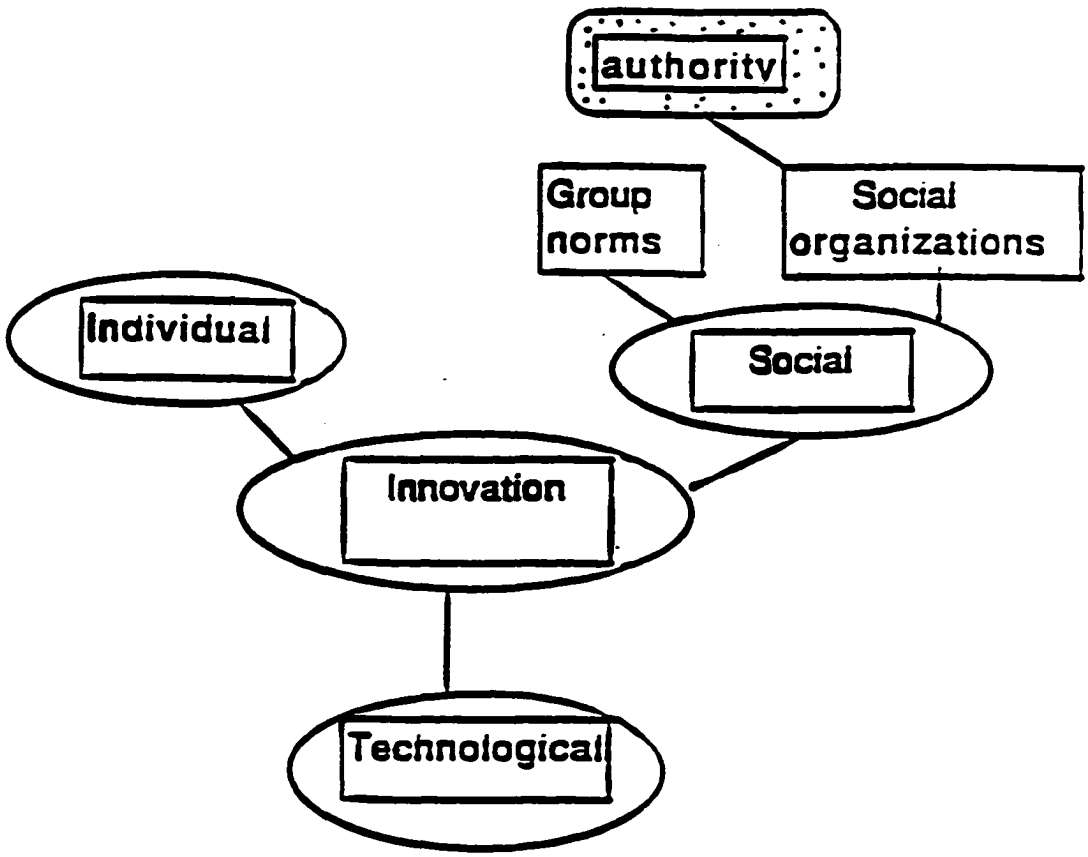

Figure 10. Authority within social systems, such as work places, have the power to influence the process of innovation.

affected groups, such as the foresters and employees, may resort to behaviour that may make the adoption of the inventions easier or more difficult.

Motivation theory and sociology may be used to determine some of the possible actions people may resort to when forced to change. If the innovation is perceived to improve the satisfaction of an individual or group, the new idea may be readily adopted. For example, wide-tired skidders were widely adopted within seven years of their introduction by forestry companies in Canada (Young and Wiltshire Inc. 1991). Wide-tired skidders enable harvesting companies to obtain higher productivity and greater seasonal operating flexibility. By using wide-tired skidders, companies can harvest areas traditionally limited to the winter season only. Further, the invention is compatible with the conventional mechanical infrastructure and methods of logging. These factors probably provide strong motives for forestry companies to adopt wide-tired skidders. Individual skidder operators also accrue benefits by adopting wide-tired skidders. They may improve their employment prospects by being able to work year round rather than only when the ground is frozen. Further, wide-tired skidders are more comfortable to operate than conventional skidders.

When authority is used to make changes perceived to affect a person's interest negatively, the individual may directly or indirectly attempt to sabotage its use. Direct actions against a new idea are obvious, such as damaging new equipment, boycotts, labour strikes, and the like. Indirect methods are more subtle but just as effective. They may include developing coalitions with others to change the decision, withdrawal from the group, or partial adoption of the new idea. Partial adoption may take two forms:

1) Individuals may meet the lowest standard or level and claim to have met basic obligations for using the new idea.

2) Individuals may postpone use of the new idea for as long as possible.

The use of power by people in authority may make it a tempting method to spread the adoption of new ideas. However, the behaviour of individuals through direct and indirect action is a strong counter measure that can limit the usefulness of authority in affecting innovation.

Organizational Types and Innovation

Formal organizations may also be classified into the type of activity they are involved in, such as manufacturing or service, profit or nonprofit, free-market or regulated monopoly, etc. (Fig. 11). Each type of organization has its own rules of conduct. For example, a manufacturing company may behave similarly to other companies in certain conditions. The generalized behaviour, such as response to threats, of formally organized agencies can be used to investigate how they may affect innovation.

Innovation in For-Profit Organizations

Motivation theory suggests that people will be driven to change when faced with external threats. For-profit organizations operating within a free-market economy are under constant threat from competing firms. Motivation theory suggests that for-profit organizations will be driven to innovate in ways that will ensure their survival and growth.

People will be motivated to change their behaviours if they believe new actions will increase their satisfaction. According to economic theory, for-profit organizations can retain their marginal gains that may result from changes that improve their profitability. The increase and retention of marginal economic gains can serve as a strong internal motive to for-profit organizations to be innovative.

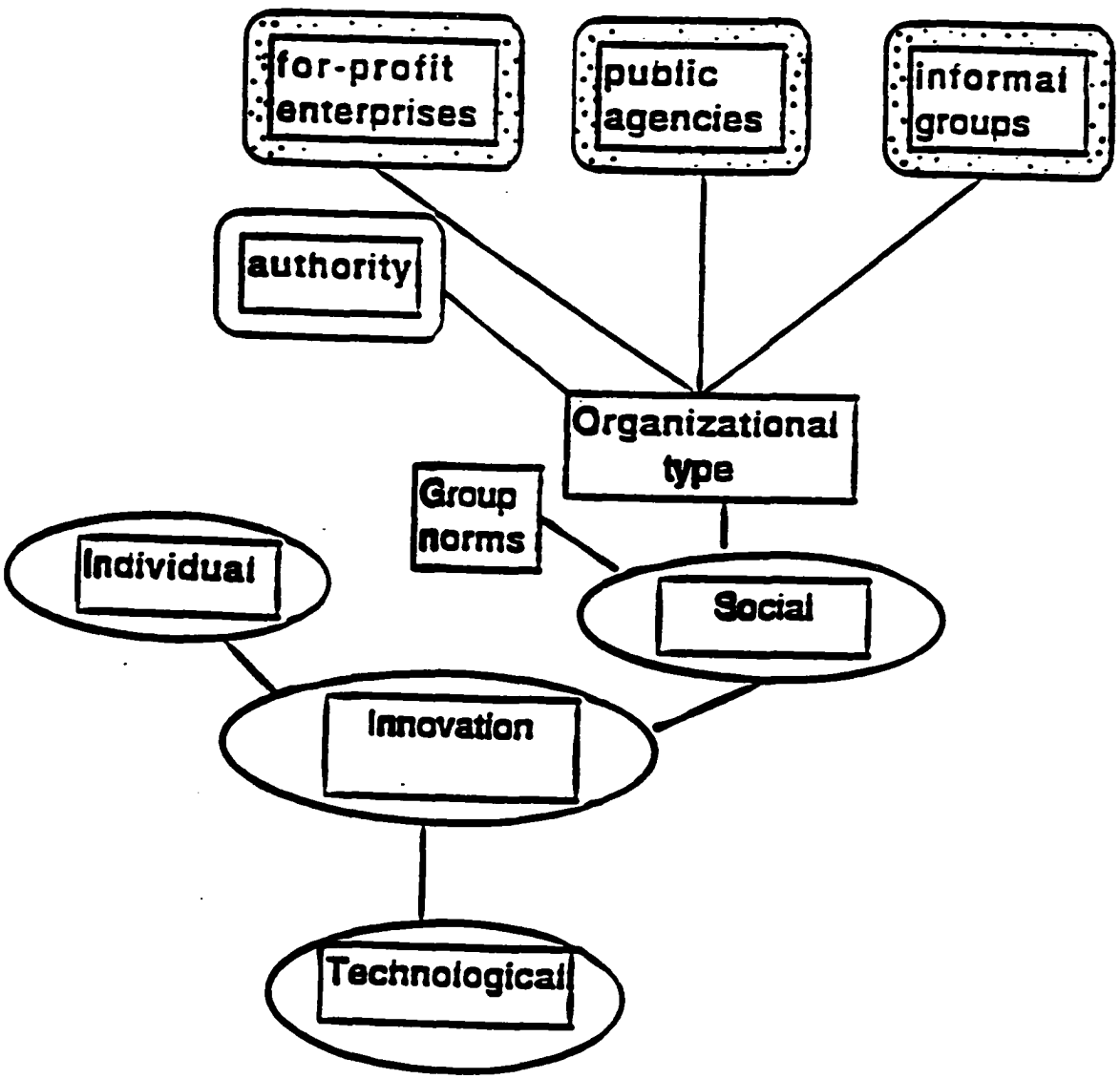

Figure 11. Social systems may be grouped into organizational catagories. Innovation is affected by the general rules and norms that control the activtity and behaviour of each organizational group.

Motivation theory suggests that innovativeness by for-profit organizations in free markets will occur primarily in areas where there is a threat or potential benefit. The threats posed by free-market competition are primarily economic. Similarly, the internal motive of for-profit organizations is also predominantly economic. Innovations that provide the organization an economic advantage, such as increased profitability, should have a better chance of being produced and used. While innovations that tend to reduce the organization's economic advantage, such as those that create social or environmental benefits but no real economic benefit, would have a lower chance of development and use.

There are many examples of inventions whose rates of spread may be partly explained by economic and motivation theory. Consider the alternatives available for managing vegetation in established forest plantations, such as manual or motorized brushing, herbicide application and browsing. Of these choices, herbicides are the least expensive (Buse *et al.* 1994). If only some for-profit organizations use non-herbicide competition control, they may become less competitive and subsequently have lower marginal economic gains. The non-herbicide methods, however, are perceived by many to have greater environmental and social benefit. Motivation and economic theory suggest that greater adoption of the more costly non-herbicide methods will be low by organizations that must compete with others that can use the less expensive method.

Motivation and economic theory suggest that innovation may also be affected by:

1) Groups other than competitors that can cause external threats. For example, consumers may apply economic threats to organizations they perceive as not conforming to their ideology. Similarly, citizens in democracies may legislate changes.

2) Societies that can create operating conditions that complement the internal motives of organizations and also the wider interests of the public. For example, regulations may be

developed by governments to ensure for-profit organizations can gain an economic advantage from an innovation that serves the public's interest.

A specific example may serve to illustrate how government regulations may be made to serve both the self-interests of individual for-profit organizations and the interests of the public. Milliman and Prince (1989) evaluated five regulatory regimes and their influence on technological change in pollution abatement. Their analysis shows direct control, i.e., setting limits on emission levels and penalties for non-compliance, provides the lowest incentive to promote technological change. They found the highest incentives to promote the creation and use of new methods to reduce pollution is the use of emission taxes and auctioned marketable permits. Auctioned marketable permits are annual permits auctioned by government to all competing companies. The permits allow the companies to release levels of pollution specified on their permits. The permits may then be bought and sold between companies. Companies governed under a system of auctioned marketable permits are motivated to innovate. Reducing their own pollution levels reduces the number of permits they need. Excess permits may then be sold to companies that have not innovated and thus reduced emission levels. Governments have the option of reducing the number of permits as practical methods of pollution control are developed, creating a higher market price for pollution. This example serves to illustrate one example of how society may create economic markets for economic entities, i.e., for-profit companies, for the achievement of social and environmental goals.

Innovation in Public Agencies

Revenues from individual government agencies are usually returned to a general revenue account. Individual government agencies are unable to capture and retain marginal economic gains from innovation. Motivation theory suggests that people in individual government agencies will have

one less reason to innovate. Further, the lack of competition removes an external threat to government agencies reducing yet another motive to innovate.

Roessner (1977) says that political science, organizational and public administration theories all suggest that government agencies would be less likely to innovate. Political science theory suggests that public accountability and frequent leadership changes should result in the application of immediately visible, flashy innovations. Frequent changes of key authority figures, i.e., elected officials, reduce the time available to obtain approval and complete changes. Innovation may take time to complete and so will be less likely to occur. Public accountability makes government agencies open to a large number of groups with different ideologies. Each group may want its own ideology reflected in the policies and operations of government agencies. Finding common ground between the different ideologies may be difficult or impossible. It may result in no changes occurring, or substantial opposition to changes that are perceived to affect the interests of some groups negatively.

Organizational theory suggests that government agencies are expected to operate predictably and treat their clients equitably. Individuals, in government agencies, can be penalized for failure, perceived to reduce predictability and equitable treatment of clients. This may lead government agencies to develop uniform rules of service and operation, which would restrict local innovation. Public administration theory suggests that government agencies have unclear goals and performance measures. For example, how does one measure ecological sustainability? Without clear measures of success, individuals in government agencies will not be able to find errors, and evaluate their innovations in attempting to meet their goal, such as achieving ecological sustainability. The lack of adequate and clear measures of success will limit the ability of government agencies to innovate.

How can public agencies make informed and positive choices in innovation? They can by first understanding the differences that exist between the operation, mandate, and expectations of public and for-profit agencies. Economic, political science, public administration and organizational theories say that the laws and social norms affecting the operation of public agencies are different from other agencies. Understanding these differences can help us suggest how and when innovation may occur in public agencies.

Public agencies may find innovative ways to address routine problems. Innovation of routine problems tackles only the issues that have the approval of the social system. For example, there would be little risk of social dissension of a government forester trying to improve methods of estimating the number of plantable spots. However, innovations that require us to perceive events in a new way can result in considerable disagreement between different individuals and groups. Consider the changes needed to move from sustainable use of resources such as wood fibre to managing human activities to ensure a sustainable ecosystem. People have to undergo a major transformation in their values, feelings, and perception to accept such a change. Innovations that cause or consider these types of changes that challenge the conventional views of the public are less likely to occur or succeed.

To improve the detection and correction of routine and non-routine problems, public agencies may want to use the strategies employed by individuals working within conditions hostile to innovation. Individuals use surplus resources for their own hidden innovative projects in what may be called "skunk works". Often these projects find and correct problems that are not discussed or addressed by a social group. Public agencies may want to ensure that they have or are able to allocate resources to creative investigators.

Public agencies could probably escape hostile reactions by attempting new ideas away from areas

where conflicts are occurring. Public agencies may feel compelled to act where the conflict occurs. For example, new means of controlling vehicular access may be applied to areas where fly-in tourist operations and logging operations conflict. Political science theory suggests that public officials will want to ensure people feel something is being done and attempt to apply solutions immediately. However, in such situations the innovation may become the symbol of the conflict, limiting its success. By trying out new ideas at correcting an error in a more neutral location, the innovation may have a greater chance of having a fair evaluation of the innovation.

External threats are a motivating source for people to detect and correct problems. A public agency and the individuals within the agency are usually immune to external threats. For example, in a conflict between fly-in tourism and logging, public agents are usually not threatened by the potential loss of their source of income, a threat felt by the tourist and logging operators. Public agencies should document these conflicts and complaints from their clients as a formal index of external threat. The number and frequency of these conflicts may be used by administrators of public agencies to evaluate the job-performance of their staff in correcting these problems from recurring.

To ensure that non-routine errors may be detected and corrected, public agencies may want to ensure that their clients and stakeholders are aware of new information, its use, and potential implications. This is a difficult task. It is subject to the norms and ideologies of each of the various individuals and groups. However, for change to occur, all individuals who may be affected must be given a chance to understand the new information.

Innovation in public agencies is complicated and is expected to be slow because of the large number of people that may be affected or have an interest in the activities of the agency. For new ideas to be used, the ideas must first be compatible with the ideologic values of the public served

by the agency. In democracies, public agencies may be limited in their ability to lead in the use of new ideas. Ideas that are not compatible to current public values will not be supported by the public, which in turn may discourage public institutions from attempting them.

Informal Organizations and Innovation

People may organize informally into groups such as communities or interest groups. These groups usually have a common ideology, sharing perceptions and goals (Weber 1992: 176). The ideology may be the only source of rules by which the group functions. The informal organization may not have formal rules that govern relationships, and may be quite dynamic in the segregation and integration of tasks. For example, leadership may change rapidly based upon internally held opinions of the people in the group. The people considered leaders by others are called opinion leaders.

Opinion leaders may also be found in formally organized groups. Opinion leadership is not based upon formal lines of authority. For example, a manager may not be the opinion leader to members of his or her company. Opinion leaders are people whom others find have ideologies similar to their own. They are also perceived as more competent or of higher social status (Holland and Kobasigawa 1980, Rogers 1983: 282).

Innovation diffusion studies tell us that people do not adopt the use of an invention just by becoming aware of it. They may decide to adopt the use of the invention only after being influenced to do so by their opinion leaders (Rogers 1983: 271). Motivation theory suggests that people seek approval, acceptance, and recognition from others. Opinion leaders can influence others in their social group, possibly by providing others with the necessary social approval and acceptance to use new ideas.

Opinion leaders may obtain new ideas from people outside their social group. They are more likely to be influenced by external sources (Rogers 1983: 282). The followers of opinion leaders are more likely to be influenced by people from within their social group. Opinion leaders are able, or willing, or allowed by others to try new ideas. Followers are less likely to try, or be allowed to use new ideas derived from external sources. For example, foresters who are opinion leaders may be more likely to obtain and use ideas developed by other professionals such as wildlife biologists, computer specialists or accountants. Foresters that are followers would be less likely to seek and use ideas from other professionals. They are more likely to use new ideas once others in their social system have adopted their use.

It follows that groups that do not share the same opinion leaders will be less likely to accept similar new ideas. For example, the use of the same new ideas between professional foresters and environmentalists may be limited if they do not share the same opinion leaders. In such cases it may be difficult to convince a member of one group to accept the ideas of another group. Innovation, particularly the spread and use of ideas between groups, may be limited unless opinion leaders are shared.

Our ideologies are formed by learning and may be modified by learning. Groups that want to innovate cooperatively should seek opportunities to learn from common and shared experiences. For example, foresters and environmentalists may establish common experiments and share data to test their assumptions. Such experiences may provide people with the learning opportunities that enable them to develop greater similarities in their ideologies.

TECHNOLOGY AND INNOVATION

People use technology in almost all their endeavours. Technology is the use of knowledge and skill to achieve a goal (Hodson and Sullivan 1995: 184). Technology enables people to expand the influence of their physical and mental capabilities. For example, technology permits people to move large logs, greatly expanding the physical strength of the people involved in the transport of logs. Technology consists of four major components:

1) It consists of hardware used to achieve a goal. For example, the hardware of a logging camp consists of the physical structures that house workers and equipment, logging equipment such as skidders, harvesters, and chainsaws, and office equipment such as computers, telephones and radios.

2) The second component includes the systems that link and organize the hardware together so that the goal of the endeavour may be achieved. In the case of the logging camp, the technological system would link the harvester and skidder, the garage to the mechanized equipment, the telephone to the radio, etc. Various combinations of technological systems are possible, each with its own consequences on the goal of the endeavour.

3) Knowledge and skill are the third component of technology. Knowledge and skill are required to organize and operate the hardware and linking systems so that the desired goal can be attained. Knowledge and skill are also required to respond to the variability in operating conditions that may be encountered in trying to attain the desired goal. Loggers may have to deal with variable terrain and a mixture of different stands of trees. Their knowledge and skill may be used to traverse the forest to ensure the right mix of tree species and log qualities are available for the wood-using mill.

4) Technology also consists of materials that are used or converted to produce a good or service. For example, a logging camp will use trees and convert them to logs.

For an innovation to occur in a technological system, it must be compatible with existing technology, or individuals must be willing to put new technological systems in place. Innovation will not occur if a change cannot be used within a technological system. For example, new knowledge generated by researchers may spread to individuals in a technological system. The individuals of a technological system may be aware of the new knowledge. However, they may not have the hardware, software, materials, or organization to use it to achieve their goals. Similarly, individuals may have hardware, but not the materials, knowledge, or organization to use it. Consider the use of Geographic Information Systems (G.I.S.). An organization may have the computer hardware and software for a G.I.S. However, without digital landscape data or trained people to run and maintain the hardware and software, such technological systems cannot function.

When the innovation is compatible with the technological system, a change in one component may affect the whole technological system. Changing from bucksaws to chainsaws resulted in changes in knowledge required, the hardware to maintain the chainsaws, and the system that linked loggers to a skidder, and resulted in higher material processing productivity.

Changes may also occur outside the technological system. People use technology to interact with their physical and social environments. For example, a logger may use a chainsaw to cut down a tree. The logger interacts with his or her environment through technology: the chainsaw. Changes made in the technological system will result in changes to the physical and social systems that the technology operates in. Consider the changes that may occur in log-moving technology. A person may seek to increase log-moving productivity by changing to faster, more powerful and larger

skidders. These changes may result in the desired higher productivity. However, it may also result in a higher debt load, the need for fewer workers and a greater potential of soil compaction.

Technology is used to help individuals and groups achieve their goals. Motivation theory suggests that people will use technology to increase their satisfaction. A person would consider an innovation desirable if it helps him or her to achieve a goal more effectively or efficiently. For example, an individual may consider using a technological innovation if it reduces his or her costs compared to the current way of doing things.

Innovation in technology tends to focus on the detection and correction of routine problems, i.e., those problems that relate to improving how something is done, such as the productivity of harvesting trees. However, the interdependence of the social, technological and physical environments suggests that changes may result unknowingly in the social and physical environments. These changes may result in the unforseen negative consequences of technological innovation. Many of these changes may be small when the technological innovation is new or used by only a few people. Once it has been used for a period of time or has been used widely, its cumulative effects may be detected.

Inventions have both positive and negative results. We may want to have only the positive effects of technological innovation. Rogers (1983: 383) argues that it is almost impossible to separate the positive and negative effects of an invention. The collaborative model of learning suggests that a new innovation cycle must start if the negative effects of technological innovation are to be reduced. To reduce the problems caused by innovation, people must innovate further.

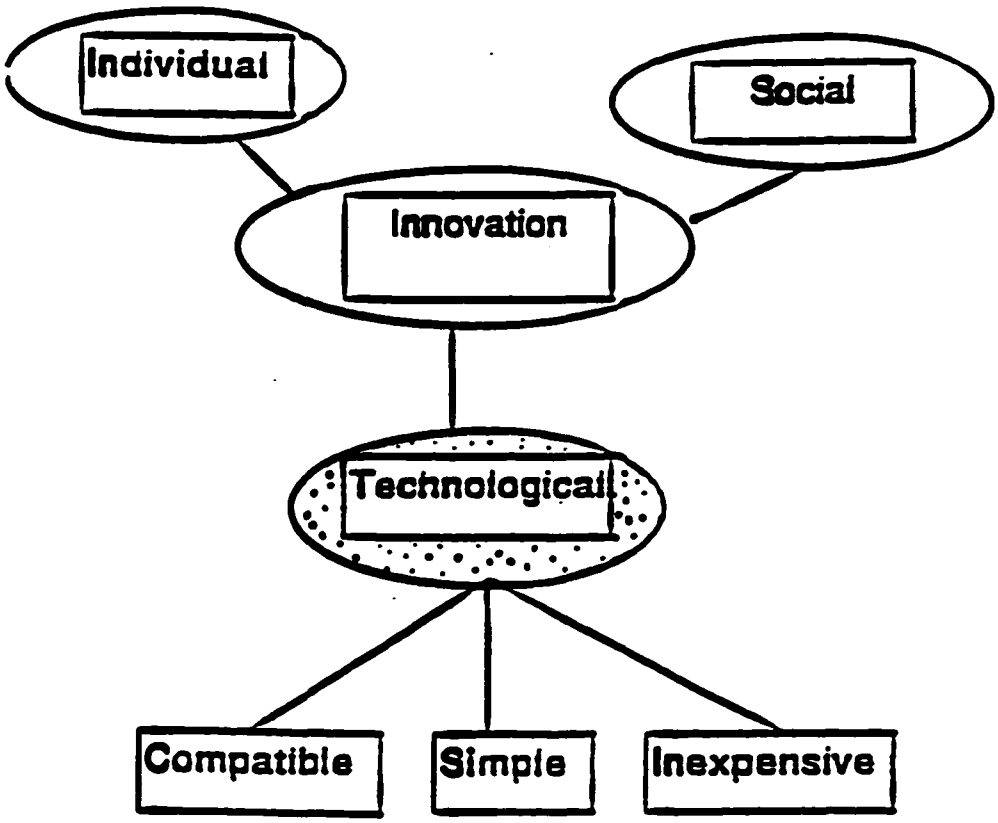

Figure 12. Factors of technological systems that affect innovation.

Technology and the innovation process

Innovation is affected not only by psycho-social factors, but also by the technology involved (Fig. 12). Innovations that are compatible with existing technological systems are more likely to be adopted (Rogers 1983: 224-225). The technology must be compatible in each of the categories that characterize technology: hardware, organization and use of the hardware, knowledge and skill, and the materials that are to be processed. Compatibility reduces the monetary, social, and learning costs necessary to make a change.

Complex, unique and expensive technology reduces the opportunity to find errors, invent, or evaluate new ideas. Simple technology increases the likelihood of people understanding it and finding ways that it can be improved. Similarly the more people involved with the technology, the more likely someone will find ways of improving it and cause a change.

Technological change may be fairly easy to make due to the innovation bias of organizations in the economy. Some changes may cause known negative consequences. Legislation may be used to control known or perceived negative consequences to society or the physical environment. Pollution control measures are an example of such regulations. Changes in technology may also create unexpected changes to economic, social or environmental systems. The use of the wheeled skidder saw the demise of small farms that maintained draught horses used to skid logs. Addressing unexpected changes is more difficult. It requires the evaluation of inventions and the ability to discover the error in its use or misuse.

USING THE COLLABORATIVE LEARNING MODEL TO IMPROVE INNOVATION

Everyone, at some time, has been involved in innovation. It is not limited to geniuses, scientists, or specially trained people. If innovation is to truly occur, everyone must be involved and have a better understanding of the process. The collaborative learning model can be used to develop a framework to improve innovation within a social system such as a community or workplace.

The model suggests that one must consider innovation from two perspectives if one wants to improve in its practice. First, innovation must be considered within the context of the learning process. The learning process enables one to determine where one is in innovating, and how to proceed through the remainder of the stages in the process. Second, innovation must be considered within the context of the social and technological system it is to occur in. Individual, social, and technological factors interact and affect innovation. By understanding one's particular social and technological context one can improve one's ability to innovate.

THE INNOVATION PROCESS AND SUGGESTIONS FOR IMPROVING INNOVATION

The collaborative learning model of the innovation process describes a four-stage process (Fig. 4). Society emphasizes the invention part of the process. Discoverers or creators of new knowledge are acclaimed and honoured. The great importance society places on invention may lead people to associate innovation with only the invention stage of the process. However, the best inventions are of little use if the other stages in the innovation process are not completed. Further, work centres may be designed to conduct only some stages of the innovation process. For example, a

manufacturing plant may not have the means to test and evaluate their products in the settings that their customers may use. Two suggestions are offered to help one to improve one's innovation practices.

Suggestion 1: *Determine where one is in the innovation process.*

To proceed with innovation one has to know at which of the four stages in the innovation process one is currently at. Once one has found the stage one is at, one can attempt to venture into the next stage. For example, a research laboratory may become aware of an error and create an invention. By being aware of the stage the research laboratory is at, individuals in the research laboratory can determine the next stage that they and their collaborators must undertake to complete the innovation process.

Suggestion 2: *Institutionalize each stage of the innovation process within one's social system.*

Each stage of the innovation process must occur for innovation to take place. Individuals in a social system, such as a work centre, must ensure each stage of the innovation process can occur efficiently and effectively. Often only a few stages of the innovation process are institutionalized within one social system, such as a work centre. For example, a manufacturing plant may be primarily involved in the production and distribution of an invention. Without the evaluation of the invention, detection of errors, and creation of new inventions, the manufacturing plant will be unable to compete with other similar plants, and will become obsolete. Similarly, a government research laboratory may be focused on the creation of inventions. The efforts of the publicly funded researchers in the laboratory may be wasted if the inventions are not used for public benefit, evaluated, and errors within these inventions worked on.

Each work centre does not have to have departments that work on each stage of the innovation process. The individuals in the work centre may collaborate with others, such as customers, suppliers, or other similar institutions, to ensure that all four stages of the innovation process occur effectively. For example, a government research laboratory may develop linkages with its clients to evaluate and detect errors of inventions it has created.

SOCIAL SYSTEMS AND SUGGESTIONS FOR IMPROVING ON INNOVATION

The collaborative learning model suggests that the cultural context is important in the innovation process. The creation, awareness, and use of new ideas in an individual are affected by factors related to the individual, such as one's learning skill. It is also affected by relationships with others in one's social system. One has to consider the explicit and implied rules that govern behaviour in a social system if one hopes to improve the process of innovation. Following are four suggestions related to the cultural context of innovation.

Suggestion 3: *Try to become more aware of the assumptions that form one's ideology.*

A person's beliefs, values, biases, and attitudes screen one's experiences. They enable a person to respond quickly to routine experiences, but limit new learning. In order for a person to detect and attempt the correction of non-routine problems, one has to be aware and question the assumptions that form one's ideology. By being more aware of the assumptions used in one's ideology, one becomes more aware of the limits of one's knowledge. The individual may then use this information to seek or create new knowledge. For example, individuals that proposed and used the Ontario tube seedling container in the 1960's (Heeney 1981) believed seedling roots would grow down the hard plastic container and then outwards. Had they been aware of their assumption and tested it, they would have discovered their belief was wrong. In most cases the root systems balled

up within the container, resulting in low seedling growth and high mortality.

Suggestion 4: *Create opportunities for innovation.*

Individuals are motivated to innovate when they perceive benefits in causing and accepting change. The benefits of innovation are both tangible, such as increased convenience, and intangible, such as an increase in social status, recognition, or acceptance. One should evaluate policies and regulations to learn if they enable people to benefit from causing and accepting change. For example, do existing rules only identify some form of punishment for doing something one's social system believes to be wrong? A case in point may be the dumping of used machinery oil in undesignated landfill sites. This action is punishable by a fine. Such regulations are not very effective in motivating individuals to find new ways to prevent the undesirable behaviour. It would be better if regulations also enabled people to obtain immediate and concrete benefit. For example, the regulation for dumping used oil could be rewritten so that people that found new ways to reuse or reduce their waste oil could obtain a benefit, such as assistance in obtaining a licence to protect and sell the process to other potential users.

Social norms are the unspoken rules that apply within a social system. Norms can affect innovation. Social systems that are tolerant of uncertainty, failure, and reward the testing of their collective assumptions have norms that create opportunity for innovation.

Norms are difficult to evaluate, particularly by individuals from the same social system. One can evaluate the norms of a social system by using expert help. The methods of sociologists, particularly those of innovation diffusion research, may be used to detect and study the norms that may affect innovation.

One can also obtain a general understanding of the acceptance and emphasis innovation receives in a social system by looking for opportunities individuals have for unsanctioned experimentation. For example, how many "skunk works" projects are there in one's social system? How easy is it for individuals to obtain and use resources to detect and correct errors without the sanction of others in the social system? Innovative social systems should have a number of skunk work projects, and be tolerant of unsanctioned experimentation.

Suggestion 5: *Reduce the risk associated with innovation.*

This suggestion is related to suggestion 4, for the outcome of reducing risk is increased benefit from innovation. However, this suggestion considers reducing risk as the direct goal, with the indirect outcome being an increase in benefits from innovation.

Risk is reduced when individuals are aware of new information, its use, and potential implications. This is difficult to accomplish particularly at the early stages of a new idea. Information on the implications of a new idea will be limited, particularly on the social aspects, such as how it may affect social status.

Risk may be reduced by adopting the following strategies to make sure individuals make informed choices:

1) encourage people to debate, evaluate, and identify missing information they need to understand new knowledge,

2) reduce isolation between groups by consulting widely, and creating opportunities for intra-group interaction,

3) create pilot or demonstration projects so individuals may see the new idea in operation in settings similar to their own,

4) being aware of opinion leaders in each group and working with them to help others make informed decisions.

Suggestion 6: *One must learn continuously and actively.*

Making informed decisions on innovation requires one to understand new information. This can only occur if an individual or group is actively and continuously attempting to learn.

What does one learn to ensure innovation will be practiced more effectively? Here are some suggestions:

1) Seek to understand information from both technical and cultural perspectives. Technical information, such as economic, mechanical, and biological information, may be easy to obtain. Understanding new information from a cultural perspective is much more difficult. It will often not be found in books, but is found by directly interacting with people in and outside one's social system.

2) Try to understand differing points of view. These may be clues to errors in the assumptions one has of new information.

3) Recognize that one will probably never have all the information one needs to make a decision. To reduce one's chances of making mistakes, imagine the possible alternate beneficial outcomes. If most of these outcomes are possible after one has made the decision, one still has the possibility of achieving a beneficial goal. For example, a forester may consider using a new silvicultural system that favours natural regeneration. The forester may reason that if natural regeneration fails, the area could still be artificially regenerated using a variety of means to obtain the stocking and composition of the desired future forest.

4) Use the experimental method to conduct technical tests. This requires one to learn by doing, to analyze the results, and use the responses from the results to continue learning. Also, use the

experimental method to question the assumptions used to form one's ideology. Question oneself actively to learn how one's assumptions change with new information. For example, an angler may believe that all fish stocking programs are good since they replace or enhance fish populations. The angler may be upset by a reluctance of a fishery biologist to stock fish in a lake with a native population of the same species. If the angler questions his assumption he may understand the fishery biologist's reasons for not wanting to introduce hatchery-raised fish into a waterbody with a native population of the same fish species. If the angler does not engage his belief and be open to change it, he will not be able to accept the new information on stocking the fishery biologist may provide.

5) Make sure that there are institutionalized methods for creating, collecting, and making available information to all members of one's social system. The information must be easily retrieved and easy to understand. With new information technology, the problem is not in making information available, but in being able to make sense of information. Usually individuals cannot make sense of the information because it provides only one perspective, such as the economic advantage of a particular method. It does not contain the whole set of information one needs to make a decision. Where information is lacking an individual should seek to have it created or compiled.

TECHNOLOGICAL SYSTEMS AND SUGGESTIONS FOR IMPROVING INNOVATION

Renewal through innovation can only take place if the current technological system is replaced. Replacing existing technological systems are not easy. It requires the creating and use of new information, new hardware, a reconfiguration of how people, equipment, and materials are organized and used to achieve the goals of a social system.

Suggestion 7: *Use small, simple, inexpensive, modular technological systems.*

Technological systems that are small, simple, inexpensive and modular are easier to change. They provide several advantages over other types of technological systems. They are physically easier to change. Being small, modular or simple may mean less space, mass and time to change, move or dispose the old technology with the new. Speed is important, particularly where delays may mean additional costs or foregoing opportunities to members of a social system. Inexpensive technological systems mean fewer resources are at risk of becoming obsolete.

SUMMARY

Innovation is often described as two processes: invention and the spread of the invention within a social system. In these reports, invention is described as some form of creative learning, and the spread of inventions as a communication process. This description of innovation is incorrect. Research in learning and everyday experiences shows that learning and communications are interrelated. To understand innovation, invention should be considered as both learning and communication. Similarly, the spread of inventions must be considered as both learning and communication.

Innovation is a process of collaborative learning by individuals in a social system. Without collaboration the rate of inventions would be lower and the inventions developed would not spread to others. By collaborating, individuals can use the memory and creative potential of many people to detect problems, develop solutions, try out the solutions, and evaluate how well the solutions have worked. In learning, individuals detect errors, solve problems and create or use appropriate inventions.

Collaborative learning suggests that three major factors can influence innovation. The first component is related to factors that are internal to an individual. These internal sensory, cognitive and other psychological factors may influence an individual's ability to detect problems, and create, try and evaluate solutions.

Motivation, past learning, and learning skill are some of the internal factors that influence innovation. According to motivation theory, individuals will only innovate if they are driven by the expectation that continuing with conventional actions will result in less satisfaction to them than

creating or using new actions.

Individuals are much more likely to detect a problem, and be able to correct it, if a similar problem was experienced and corrected in the past. The ability of individuals to transform and use past learning suggests that innovations that are compatible to learned skills, knowledge, and norms would be more likely to be created and used. Similarly, individuals that are more skilful at detecting and correcting errors would be more likely to be innovative.

The second major factor that influences innovation is the social system such as a workplace or town. Individuals may organize themselves into functional groups to achieve common goals. Organization affects the ability of individuals to interact, which in turn affects the ability of individuals to collaborate and learn from each other. Individuals within a social system learn technical information and the acceptable rules of behaviour from each other. The acceptable rules of behaviour or norms of the social system greatly affect innovation. Norms control acceptable and unacceptable behaviour of individuals within the social system. The norms of expected behaviour within different social organizations such as free-market private enterprises and government agencies affect innovation. For example, government agencies are expected to treat all citizens equitably. This may result in government agencies not being allowed to or able to develop and use some locally applicable innovations.

The third major factor that influences innovation is the technology people use to achieve their goals. Today, innovation in technology is common. Changes in technology often result in changes to the social system within it is used. Innovation in technology may also result in changes to the physical environment within which it is used. These changes within the interrelated technological, social and physical systems may result in unforseen negative consequences.

Innovation results in positive and negative consequences. It is impossible to have only the positive effects and not the negative consequences of an invention (Rogers 1983: 382-384). The only way negative consequences may be reduced is through continued innovation. Seeking to correct the negative consequences will result in seeking solutions, their trial and evaluation.

Innovation is a complex process with many dimensions. Often innovation is perceived as a rational process that should occur if the new ideas have an advantage over using traditional knowledge. Experience has shown that this is not so. Innovation involves not just rational aspects of human thinking, but also normative facets. To ensure that people make informed decisions on innovation, people must be provided with and be willing to use a diversity of types of information. People must be provided with verifiable technical information. They also need to be provided with emotional, moral, ethical and other information necessary to understand the problem or solution from a normative perspective.

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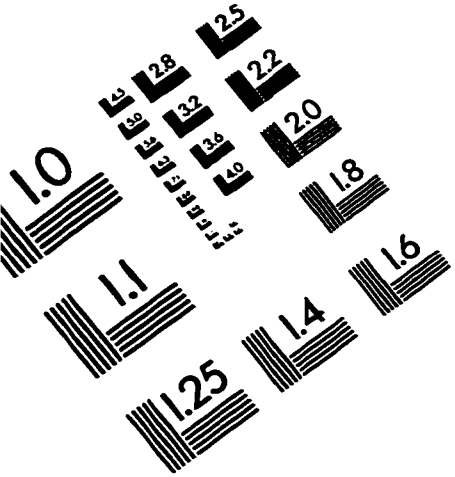
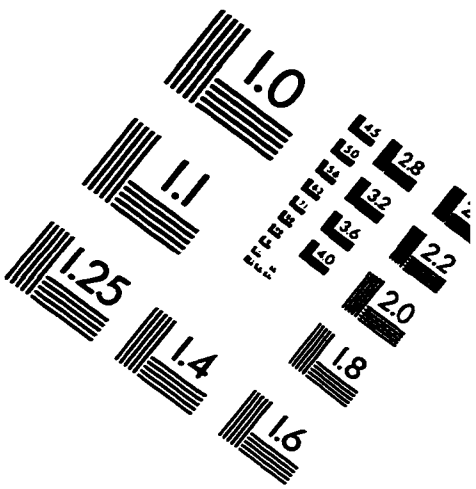
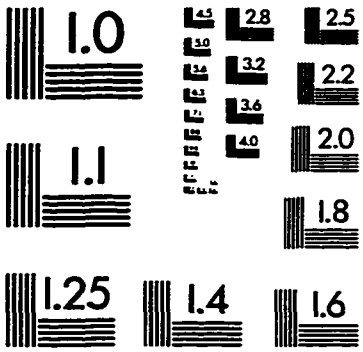
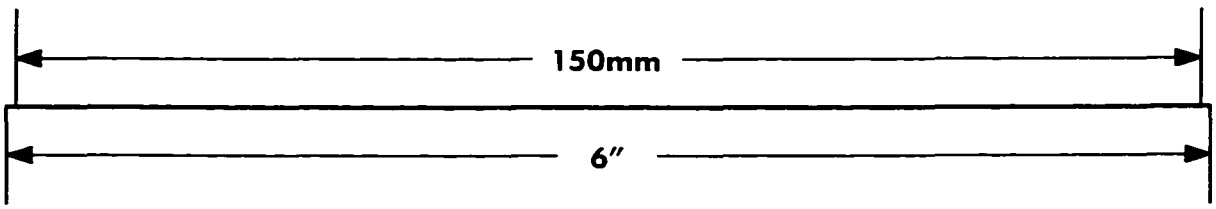
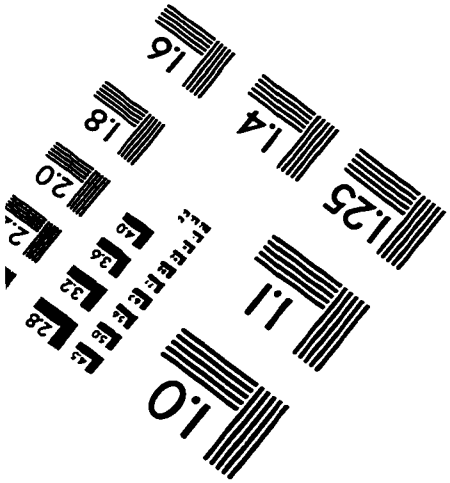
IMAGE EVALUATION TEST TARGET (QA-3)

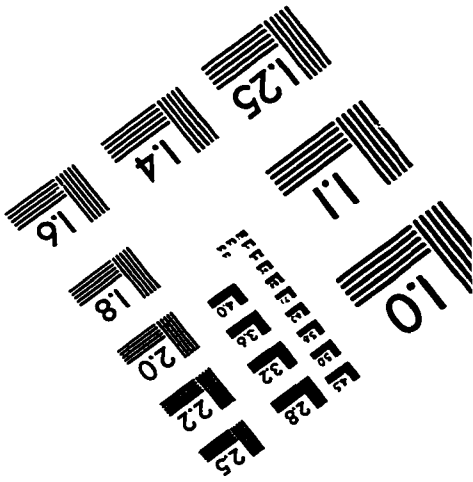












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