Systems Thinking and Practices in the Education of Agriculturalists

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SUMMARY

A systems approach has been taken to a review of agricultural education programmes and as the essential theme of resultant curricula at Hawkesbury Agricultural College in Australia. The systems thinking and practices which have guided, and been shaped by, the innovations are outlined, and the rationale and framework of the major programme are described. The subsequent emphasis has been placed on effective learning for agricultural managers and their technologist advisors. It is argued that problem solving and learning are essentially the same psychological processes and that taking a systems approach to investigating problem situations provides a more useful paradigm for learning about agriculture than reductionist, discipline-based approaches. Experiential learning and autonomy in learning are seen as consistent with this and are basic features of the programmes. A conceptual framework for problem solving that incorporates soft and hard systems and scientific reductionist methodologies has been developed. A contingency approach to situation improving is emerging as a less restrictive and more realistic alternative to a normative approach to problem solving.

INTRODUCTION

The rôle that agriculture has played in the socio-economic development of Australia in the two hundred years since European settlement occurred has been well chronicled (Williams, 1982). Formal education in agriculture has been available for almost half that time and has
undoubtedly had a significant impact on the overall production and productivity of the rural sector (Swain & Bawden, 1981).

Yet there is an increasing sense of unease that much of this has been gained at the expense of permanent damage to fragile ecosystems; systems which, before European settlement, had supported significant human populations for tens of thousands of years without cultivation or the presence of cloven-hooved ruminants (Flood, 1983). There is a fear that should contemporary practices continue, then their conflict with natural evolutionary forces might well result in continued, and ultimately irreversible, deterioration of many of the land’s resources. Yet the pressures brought on farmers to change their cultural practices to be less exploitative of natural resources have to be reconciled with the need to increase productivity to cope with increasing economic pressures.

The confusion associated with these dynamics and disequilibria in agricultural systems is the essence of Dahlberg’s (1979) contention that most intellectual maps of agriculture fail to perceive it as ‘the basic interface between people and their environments’. It has been argued that Australian educational institutions have been remiss in not developing learning environments and curricula which reflect this perspective (Bawden & Swain, 1981). It was these perceived mismatches between educational programmes and the dynamics of agriculture in Australia that led, in 1978, to a new thrust in tertiary agricultural education in that country.

A structural reorganisation within Hawkesbury Agricultural College in New South Wales gave its School of Agriculture an opportunity to redesign its curricula. The challenge was to provide programmes of learning for farm managers and agricultural technologists appropriate to the complex issues of agriculture as a human activity.

The relevance of a systems approach to the process of curriculum review and as the essential theme of resultant curricula proved pervasive. The fundamental concepts of Spedding (1975, 1979) and Cox & Atkin (1979) on agricultural systems, the analytical approaches to farm systems analysis (Dent & Anderson, 1971), developments in agricultural systems research (Dillon, 1976) and in systems thinking and practices (Checkland, 1976), were all potent catalysts to the Hawkesbury systems thrust. Learning models appropriate to the approach have drawn heavily on the experimental concepts of Kolb and his colleagues (Kolb et al., 1979), on autonomy in learning as outlined by Burgess (1977) and Boud (1981), on problem-based learning in medicine (Maddison, 1982) and on the
problem-solving systems methodology developed by Checkland (1981a) and his colleagues. Finally, the ideas of Chaudhri (1969) and of organisational systems theorists Kast & Rosenzweig (1981) have provided models for learning about agricultural management as well as for structural developments of the School of Agriculture itself.

This paper outlines the systems thinking and practices which have guided and been shaped by the innovations in the Hawkesbury educational system with its emphasis on effective learning for agricultural managers and their technologist advisers.

Essentially the re-orientation and innovations at Hawkesbury are based on:

1. Studies of systems and subsystems involved in agriculture and *not* of separate subjects or disciplines.
2. Systems and contingency problem-solving approaches to learning and *not* reductionist science and pedagogical ones.
3. Learner-centred and *not* teacher-centred teaching strategies.
4. Organisational flexibility in the School and *not* adherence to discipline-based Departments.
5. The School as a learning centre subsystem integrated into the national agricultural system *not* as a discrete and restrictive post-secondary institution.

Two basic contentions are that all things are *not* knowable and that the whole *is* indeed greater than the sum of its parts. A further belief is that studying the problems of agriculture should start with the whole situation before its reduction to constituent components.

The logic of the approach follows the sequence:

Managers and the technologist advisors of the agricultural service industries are concerned not with scientific questions of the nature 'what is?' but with questions of the order 'what is to be done?'. They have to be able to identify situations that need improving and solve associated problems. Logic dictates that their education should be about helping them become more effective at taking such actions.

Problems in agriculture are almost always concerned with things which are interacting with other things. Furthermore, these things and the way in which they interact are under the influence of changeable environmental conditions and profound evolutionary forces.
It is convenient to think of these interrelationships as 'systems of interactions'. This is associated with the fact that totally different situations have the same general characteristics of boundaries, inputs, outputs, transformation processes, measures of performance and an environment.

In spite of these common characteristics, however, systems can be divided into two major types (Ackoff, 1973; Checkland, 1981a):

(1) Those that have clear goals and/or predictable outcomes (purposive or 'hard systems').
(2) Those where goals may be unrecognisable and outcomes ambiguous and uncertain (purposeful or 'soft' systems).

The various methodologies and techniques used for solving problems in agricultural systems will therefore be contingent upon the nature of the system(s) involved.

To build an operational conceptual framework it has been necessary to develop:

(1) A model of agriculture consistent with Dahlberg's (1979) perceptions of it as 'the basic interface between people and their environments'.
(2) An approach to problem-solving that allows for the complexity and lack of definition of real world problems.
(3) A concept of the teaching/learning process that will enable the educational aims to be achieved.

(1) A MODEL OF AGRICULTURE AS A HUMAN ACTIVITY SYSTEM

Figure 1 is a diagrammatic representation of farming systems as a human activity system. It reflects the perception of agriculture which underlies the Hawkesbury programmes.

Farming systems are key ones in the hierarchy of systems which represent agriculture, but not the only ones. Management is common to all and the innovating–allocating–operating model of Chaudhri (1969) serves a useful purpose. Kast & Rosenzweig (1981) envisage the
Fig. 1. A model of farming as a human activity system.
management of an organisational system as comprising three interrelated subsystems or levels of goal-directed activity:

(a) At the operations level the primary task is carrying out stated objectives effectively and efficiently. Objectives tend to be 'optimising' and problem-solving techniques have a basic computational focus. Operations are relatively insulated from changes in the systems environment and hence comparatively stable and fixed.

(b) The strategic and innovation level is concerned with relating the organisation with the environment, developing strategic plans and providing adjusting mechanisms to cope with changes. Objectives tend to be 'satisficing' and problem solving had a judgemental focus. The strategic level is relatively open to the systems environment and innovations are responses to its dynamic and variable nature.

(c) At the allocating and co-ordinating level the primary concern is integration of the internal operations and allocation of resources in a way that is consistent with overall strategies.

The smaller the organisation, and this pertains especially to the family farm, the more likely it is that only one or a few people will perform all of the three functions. As organisations grow the functions are differentiated—as in an educational system, for instance.

Agricultural education tends to focus on the aspect of managing that reflects a background of the policy-makers, often without recognition of it as an aspect of managing. Agricultural scientists tend to focus on operations: farm management economists on allocations; macro-economists on the strategic level. It is rare to find an operational conceptual framework for educational policy which encompasses all three. A systems paradigm and an understanding of the function of technology may be prerequisites.

(2) APPROACHES TO PROBLEM SOLVING

The intellectual framework for approaches to problem solving is built on four generalised models of ways agricultural problems are, or might be, approached. All four are incorporated and selection is seen as a matter of judgement contingent on the situation. The models are seen as
representing a hierarchy of approaches to problems of increasing complexity and lack of definition. The four approaches are:

(A) A reductionist scientific approach.
(B) A reductionist technological approach.
(C) A hard systems approach.
(D) A soft systems approach.

The choice of one or the other is influenced by the objectives to be achieved, the context of the problem and the abilities (often related to the education received) of the problem solver. These differences can be illustrated as sequences of key events in each process.

(A) The reductionist scientific approach

![Diagram of the reductionist scientific approach]

This approach relies on reducing the problem to some testable proportions, experimentally testing the resultant hypothesis through some sort of objective quantification and by the reduction of as many variables as possible, deducing an ultimate output in the form of a 'this is why' statement.

(B) The reductionist technological approach

![Diagram of the reductionist technological approach]

This reductionist technological approach is common in applied research typical of agricultural science (in fact, agricultural technology) where the
focus is on 'what is to be done?' and not 'what is?: why is it so?'. Furthermore, and as a direct result of its use in the applied research context, it is both the basis for most technical advisory services and, as refined by financial data, farm management services in Australia. Of course, the methodologies used, as well as the parameters measured to seek technical optimising solutions, will differ from those used for economic ones but the essential process of quantification remains the same. This approach, whilst certainly having some major benefits in increasing agricultural productivity, has caused many compartmentalised efforts. It is only recently that technologists of different disciplines have started to work together in multidisciplinary teams to provide less-reduced solutions.

There is a big step to be taken, however, between aggregations of multidisciplinary approaches to problem solving and holistic or systems approaches.

(C) The hard systems approach

The crucial third step in this sequence is not the reduction of the problem as before, but its statement in the context of a descriptive system. This system is then modelled. This is a fundamental conceptual step to take in
the transition from reductionism to systems thinking. The systems model will include a recognisable boundary, inputs, outputs, essential transformation and some parameters of performance. Subsystems and their interactions will be identified and mathematical relationships sought. Once the model has been constructed—a simulation of the real world, often built using data generated by the reductionists—it can be used to:

(i) Predict outcomes of various alternative strategies and thus act as an optimising model for the system in either physical or economic terms (systems analysis).

(ii) Permit a whole new system to be built or 'engineered' which will solve the problem in a more fundamental sense (systems engineering).

(iii) Highlight key factors of environmental influences and inter-activities in the behaviour of the system as well as indicate where deficiencies in the current scientific knowledge may lie (systems research).

Systems analysis has gained a number of adherents over the past few years and many models have been developed to calculate optimising strategies for such functions as rotational grazing (Morley, 1968; Noy-Meir, 1976), irrigation water application (Cull et al., 1981), fertilisation rates (Bowden & Bennett, 1974; Helyar & Godden, 1977), and pest management programmes (Teng et al., 1978). The engineering of new agricultural systems is far less commonly practised, probably due to the difficulty in defining all of the variables involved in purposeful activities. The approach to the design of cropping systems developed at the International Rice Research Institute (Zandstra, 1977) is a clear attempt at engineering systems, although, as with any innovation, there are certainly difficulties associated with the real adoption of such computationally designed farming systems.

It would seem that systems research, the third activity referred to above, is a stated objective of most systems modellers (Dillon, 1976), although evidence is scarce as to its actual rôle in determining research priorities.

It is not uncommon for any of these studies to commence with the modelling of a system rather than the recognition of a particular problem situation. All of these systems activities are based on the premise that quantifiable objectives or purposes can be clearly set for the task to be
elucidated. All are being used with increasing frequency in agricultural situations, especially at the operations and allocations levels of activity. The key to the essentially numerical nature of this approach is the computer and the main technique used is simulation modelling.

These approaches are less useful when the goals or purposes of a system are vague and non-quantifiable, like those involving organisational strategies, human values or the exercise of political power. Under these circumstances a fourth approach is needed.

(D) The soft systems approach

This methodology, developed over the past few years by Peter Checkland and his colleagues at Lancaster University (Checkland, 1981a) is of potentially great significance in dealing with the multitude of unstructured problems that characterise human activity.

Naughton (1981) gives an overview of this methodology in which he states that it is based on the assumption that a real-life 'mess' might contain hundreds of problems and that the idea of problem solution for the situation as a whole is a 'Utopian dream'. The analysis phase is therefore conceived of not as an attempt to arrive at some objective understanding of the problem, but as a phase during which different perceptions of the situation as a whole may be represented and communicated. The analyst is expected to help people in the situation make meaningful improvements rather than simply presenting them with a list of recommendations for action. This means the analyst himself is an actor in the problem situation.
The methodology is a systems one because of the centrality of the concept of a relevant system within it. Once the analyst has focused on those aspects of the situation he wants to explore further he is required to imagine a systemic way of making it better or perceiving it in a different light as a relevant system. This system is then developed through the rigorous application of systems thinking to defining it and building a conceptual model of it. The comparison of the model with the real-world situation, and the insights this provides, are the basis of a debate about desirable and feasible change among the people involved.

Checkland (1981b) maintains that hard systems problems are a special case of soft ones in which a clear statement of purpose enables optimising systems to be developed.

The methodology has been found to be a very useful one in the learning by tackling real-world problems context of the Hawkesbury programmes. It is consistent with the view of agriculture as an interaction between social and natural systems and the innovations/strategy–allocating/coordinate–operating concept of managing agricultural systems. It stresses the need for the creative, perceptive and intuitive mode of thinking which characterises the artist as well as the logical, linear and sequential thinking often thought of as the province of the scientist (Samples, 1976; Vickers, 1981). It also calls for skill in human relations. It is clearly a technological methodology in that its primary goal is effective action, the facilitation of beneficial change in problem situations, rather than understanding for understanding’s sake.

The intellectual map of agricultural systems and problem-solving methodology that has been developed incorporates all four approaches. Selection of an appropriate approach is a matter of judgement and is contingent on the particular situation. Thus the feature of the ‘Hawkesbury map’ is the hierarchy of approaches to problems of increasing complexity and lack of definition.

(3) LEARNING ABOUT AGRICULTURAL SYSTEMS

The emphasis on the management and technological aspects of agricultural systems, including farming ones, reflects a view of them as human activity systems. The three managerial subsystems referred to can be identified in all agricultural systems, be they farms, extension services, educational institutions, credit organisations, marketing boards or
Fig. 2. A model of the problem-solving/learning process.

Problems start with a situation of perceived mismatches being experienced. David Kolb and his colleagues suggest that effective problem solving proceeds from this first step as a cyclical process involving three more steps of (i) observation and reflection; (ii) conceptualisation and generalisation; and (iii) action to validate (Kolb et al., 1979). This process is illustrated in Fig. 2.

These authors have concluded that this process is identical to the way people naturally learn about anything and thus effective learning contains the same identifiable steps. This view of learning has been termed experiential learning as it relates to the close relationship between the learner and the realities being studied (Keeton & Tate, 1978). Since problem solving often has a negative and restrictive connotation, 'situation improving' might be a much more acceptable concept. It is certainly more consistent with the principle of action learning.

The experiential, or action learning approach, dictates a number of characteristics which learning environments must reflect (Bawden, 1983):

1. Learning is a lifelong process and the extent to which it is practised is the responsibility of each individual learner.

2. The design of relevant curricula should recognise that individual learners:

   (i) should be encouraged to assume as much responsibility as possible for identifying and fulfilling their own learning methods;

   (ii) have different learning needs and goals from others who are entering the same career pathway;
(iii) differ in the manner in which they improve their own learning abilities of acquiring knowledge and skills and developing attitudes and beliefs;
(iv) differ in the rate at which they learn, not only between individuals but for the same individual on different occasions;
(v) learn more effectively when fulfilling self-set objectives rather than objectives set by others.

(3) Learning outcomes are more easily achieved and capable of assessment when initial objectives are clearly stated and the context to which they refer defined.

(4) Learning is more effective when the learners are actively involved in learning experiences rather than being passive listeners to facts being taught or skills demonstrated to them.

(5) As learners assume increasing responsibility for their own learning this should be accompanied by increasing responsibility for self assessment.

This view of the learner, or situation improver, as someone actively thinking and doing things about life situations being experienced, closely reflects the educational philosophies of such writers as Rogers (1969), Tough (1971), Freire (1972), Illich (1973), Knowles (1975) and Burgess (1977). The inference from these works is that learning is a continuously recurring process through life for which the learner assumes responsibility and control.

**THE CONCEPTUAL FRAMEWORK IN PRACTICE**

Putting this conceptual framework into practice has led to major changes of this School's programmes and the organisational context in which they are offered.

The innovations–allocations–operations model has been used as a guide for the reorganisation of the School. A form of matrix management is emerging in place of the previous hierarchical and departmentally based structure. In the new structure:

(a) Strategic planning and the identification of related developmental issues occurs through consultation with School staff, a feature of which is a weekly Open Forum.
(b) Allocation of resources and integration of internal activities of the School is done by a School Co-ordination Group, made up of programme co-ordinators and resource managers.

(c) Operations are carried out by general staff teams, with one of the team designated as a co-ordinator. Resources are provided as learning packages by staff grouped in more traditional subject-centred groupings.

The underlying assumption is that organisational structure needs to be open and flexible to accommodate rapid and unpredicted change in the needs of the learners as well as in the suprasystem of government funding policies.

The Bachelor of Applied Sciences (Agriculture) programme illustrates how these concepts are put into practice. The programme is divided into three phases: the first and third are each of three semesters duration, whilst the second is a one semester off-College phase. To graduate, students must demonstrate that they have acquired knowledge, skills and attitudes across a competency matrix of independent learning, communication and systems agriculture.

The matrix reflects the essential holism of the Hawkesbury educational environment.

The major aim of Phase I of the programme is to introduce students to systems concepts and to the Hawkesbury view of agricultural systems (Fig. 1). This is done by presenting the concepts and providing experiences to enable students to validate views of reality. These experiences include a detailed study of the College integrated dairy farm at the levels of operations, allocations and strategic planning, an evaluation of the allocation and strategic planning of other farming systems drawn from the College estate or nearby areas, and resource allocation within simulated farming systems.

At all times, the overall learning experiences are presented in a problem-solving framework, with resource packages being available to enable students to effectively analyse situations, to reflect on this analysis, draw out conceptual models and then to validate these models. The resource packages may be presented as traditional lectures, laboratory practicals and demonstrations, or as study guides, audio-visual packages, computer programs and other innovative educational strategies. Assessment is based on the student being able to demonstrate an ability to identify problems or issues from the farming system and its major subsystems, and
being able to follow through the learning cycle to propose possible validated improvements to these problems and issues.

Considerable emphasis is placed on the process of learning. Students are encouraged to accept increasing responsibility for the organisation of their own learning, with academic staff facilitating this transfer of dependency from teacher to learner. The role of the teacher in this context has been outlined by Burgess (1977), and involves the achievement of a balance between support and confrontation. The academic attempts to encourage increasing self-confidence in the student, access to learning resources and frequent feedback on the learner’s development. Much of the learning occurs in small group situations. The group process provides both an opportunity for learning to be shared and an experience base for studies of social systems, using the people-in-systems model of Egan & Cowan (1979) and the characteristics of the development of small groups as described by Bormann & Bormann (1976).

Parallels are drawn between the psychological processes involved in problem solving by individuals and groups, and effective learning through reference to the learning cycle of Kolb et al. (1979). The learning progress of students is monitored using the device of the portfolio (Bawden & McKinnon, 1980). In this students monitor their development against the course competency matrix in the affective, conative and intellectual domains.

In the second phase of the programme students are placed in commercial farming systems, mainly in the State of New South Wales, but increasingly beyond. The essential thrust of this experience is for each student to carry out a systems analysis of the farming system using the Hawkesbury model as a reference. During this phase, contact with academic staff is deliberately maintained at a low level to encourage learning autonomy. Academic staff normally only visit the farm twice and all other contact is by mail to the student’s facilitator. The learning strategy of this phase is a contract for learning negotiated between the student, the host farmer and the facilitator. Once again reference is drawn to the competency matrix and students are expected to continue to develop abilities across that matrix.

There are two major aims in the third and final phases of the programme. The first is to provide opportunities for reflection and deeper investigation of the real-world experience just completed. Students are expected to present a detailed representation of their learning attainments from the previous phase, as well as how they have subsequently fulfilled
learning needs identified at that time. The organisation and fulfilment of each individual's learning is primarily the responsibility of the learner in this phase of the programme.

The second major aim of the phase is fashioned around the development of a career competency model and the implementation of learning strategies to achieve such competency. The competency model is developed in association with an appropriate employing group, recent graduate employees, academic staff and the student. The model is based on the premise of employability in an agriculturally based career upon graduation. These careers might be as broad as the management of extensive farming systems, or as narrow as relatively specialist advisory technologists. After a minimum of seven semesters' enrolment, students may apply to graduate, basing their applications on their fulfilment of the programme competency matrix and their own career competency matrix. Such achievement is validated by a panel of academic staff and external programme advisors, drawn from the agricultural community.

A number of associate diploma programmes (2 years) and a graduate diploma programme have been developed to extend these principles to different groups of learners. In addition, a Masters in Agricultural Systems has been designed and awaits government approval for its accreditation.

FUTURE DEVELOPMENTS

The conceptual framework described has evolved since 1978. The process has accelerated during 1983 in response to the first group of Phase II students being placed in a problem-solving rôle in commercial farming systems. Staff have been under increasing pressure to conceptualise systems thinking and practices, and desirable and feasible learning environments. They have also been expected to be much more involved in the management of the School itself as an educational system adjusting to continued environmental change.

The result has been a change in the pattern of systems thinking and practice, which can be described as:

1. Away from a normative approach to defining problems in which a definition of the system being studied is the starting point:

   to a contingency approach to problem-solving in which a
comprehensive but relatively unstructured analysis leads to the definition and design of systems to improve the situation.

(2) Away from a relatively static within-system focus which places emphasis on the structure of the system and problems associated with allocation and operations:

to a dynamic focus that aims at highlighting opportunities for improvement by looking for matches and mismatches between resources, activities and changing circumstances.

(3) Away from social and personal factors being seen as a constraint to improved agricultural practice:

to an appreciation that social values and the goals and attitudes of the people involved are key elements to improving a situation.

(4) Away from the concept of a *best solution* to the key problem:

to a concept of problems as multi-dimensional sets of circumstances for which there is no 'one best way' solution.

(5) Away from a past and present time orientation:

to a future orientation.

(6) Away from an emphasis on structure:

to emphasis on process as an aid to creativity in the design of relevant systems.

The Kolbian learning cycle suggests that the next major development should be action to validate this pattern of concepts and generalisations. In practice this is likely to involve the School:

(1) outreaching into the farming community through external offering of credit and non-credit courses;

(2) increasing emphasis on real-world problem situation improvement as the focus for learning projects;

(3) developing the College estate into purposeful farming systems that are integrated and thus better able to respond to social and ecological forces;

(4) continuing to adjust and adapt the way current programmes are organised and managed;

(5) adapting the organisational structure and process of the School and College to the requirements of the new programmes;

(6) participating in the development of educational programmes with a similar orientation, in Australia and overseas;

(7) broadening the educational environments beyond agricultural systems to incorporate issues of rural development.
CONCLUSION

This paper suggests that adopting a systems perspective to problem situations provides a more useful framework for representing the real world than the reductionist, discipline-based one. It further submits that problem solving and learning are essentially the same psychological process, and the experiential cycle proposed by Kolb et al. (1979) provides an appropriate model for designing learning situations for agricultural managers and technologist advisers.

Technology relates to the taking of effective action and, as such, management is technology. However, there are certain abilities technologist advisers to farm managers need to acquire that deserve special emphasis in their education. Both vocations can be seen to involve three hierarchical levels or subsystems of human activities in operations, allocations and innovations. Each of these in turn presents differing needs for human abilities.

Many of the problems of management of agricultural systems, especially at the level of strategic planning and innovational adjustments to changing circumstances, are less than precise, and their solution is more akin to ‘improving situations’ than to ‘solving problems’. The methodologies associated with what have been termed soft systems have been found to have particular attraction to improving such messy, complex situations. Here the outcomes are not optimising solutions but constructive actions for change.

There are situations, however, particularly at the allocative and operative levels of activities, where optimising solutions can be generated. Systems methodologies appropriate to the resolution of such problems are also a desirable competency for managers of all types of agricultural systems. Computer literacy will be an increasingly important skill in this context as quantitative modelling continues to gain credence as a tool in allocative decision making. It is also a fundamental ability for accessing information fields.

Agricultural systems lie at the interface of natural systems and the purposeful activities of people. The pressures for change are enormous and are associated with those as profound as cultural forces and natural evolutionary forces. Spontaneous perturbations in both physical and financial environmental elements also provide impetus for innovative adjustments.

The importance of the interactions between members of the family on
the management of the family farm and the value systems which surround them cannot be over-emphasised. This dynamic provides a crucial context for understanding the interactions of any particular farming system with ancillary agricultural systems such as those concerned with marketing, education, advisory work and research.

The essence of agriculture is its complex interactiveness whilst its dynamics frequently result in situations which could be improved both feasibly and desirably. A systems approach helps the manager and his advisory technologists cope with these complex, and often messy, situations. Experiential learning methodologies provide appropriate ways for learning how to develop ‘situation-improving’ abilities, and implicit in such methodologies is the development of the autonomy of the individual learner.

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