New competencies for new times: teacher professional development beyond 2000*

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Abstract: Chemistry education for the past 100 years has been characterised by teacher and laboratory centred learning settings which have provided contexts which are valued by chemists to the extent that the 'folk law' about effective learning outcomes emphasises conceptual knowledge and laboratory investigation.

The advent of 'Science for All' movement coupled with rapid technological advances in computer assisted learning is providing a catalyst for alternative modes of learning, for the reduction of the learning of conceptual knowledge and a definite reduction in the role of the laboratory in the training of chemistry.

These trends are well established and will require chemistry teachers with different skills, with different learning theories and a different philosophy about what is important in chemistry education into the next millennium.

Fundamental change in teachers practice will be necessary. However history has taught us that changing the syllabus or textbook will not of itself lead to different outcomes for students or teachers alike. Mandating the direction of future chemical education is quite insufficient to cause changes in chemistry classrooms. We have failed in the past to understand or at least take into account the values, beliefs and personal practical knowledge which already characterises the current classroom practices of teachers.

This paper explores these issues and suggests alternative professional development initiatives which will need to be addressed if chemistry is to retain a viable area of interest for our youth.

There comes a time in the cycles of societies where radical breakthroughs or destruction are likely to occur. Change forces reach a breaking point. As we head towards the 21st century we are in such a period. Teachers' capacities to deal with change and learn from it and help students will be critical for future development of societies. They are not now in a position to play this vital role. We need a new mindset to go deeper (Fullan [1]).

INTRODUCTION

The theme of the 15 ICCE, 'Chemistry and Global Environmental Change' is an appropriate analogy for the challenges facing teachers at all levels of the education system. The old 'catch cry' *Think Globally Act Locally* when applied to classroom environments highlights the contradictions and challenges facing chemical educators.

Globalisation of the social, economic, political and educational foundations of world communities presents challenges which have not been present before in our national educational systems. School systems are not in a position to ignore them as the very foundations of our society are now subject to the forces of globalisation. For example the 'wired planet' is now reality and the influence of the micro

processor and the subsequent growth of the information industry has made redundant the need to 'teach' much of the 'information' which we generally include in the chemistry curriculum.

Local adaptation to the forces of globalisation will be the focus of much of the educational reform which will take place. This paper is not an argument in favour of the diminishing responsibility of teachers in the learning process. It is quite the contrary. Societies will need teachers with different skills and different role expectations. This paper discusses some of the issues and changes which are now necessary in the models of professional development of teachers.

PUSHING OUT THE BOUNDARIES

Peter Fensham in the final plenary address to the 14th ICCE in Brisbane in July, 1996 made the point that 'all of us have a tendency to enjoy the status quo and the familiar'. His summary of the conference proceedings included the observation that many of the conference topics 'created quite a defensive sense of anxiety'. Table 1 lists a number of examples where expansion of our boundaries as chemical educators was suggested. In the right hand column there are two ideas. Fensham suggested that the second idea, in italics, would cause a high degree of 'discomfort' in our current professional practice.

Table 1 Two levels of expanding boundaries in chemical education

Assessment	Use of open ended items
	use of items without a definitive 'correct' answer
Visualisation	shapes of molecules with the dynamics of motion within them
	anthropomorphism of the person/molecule
Multi-media	interactive with several levels of meaning
	confidence with these levels of meaning and with these media to use them in teaching
Public education	use of multiple modes of exchanging knowledge
	the very short time scale within which public education in chemistry must be conducted
Industrial	more imaginative and effective ways of links engaging students with chemical industry
	overcoming our own antipathy as chemical educators about industrial chemistry
Teaching Strategies	hearing about new pedagogies that enhance learning
	accepting that 'good' teaching does not automatically lead to effective learning, and surrendering traditional control
Research	more research studies with cautious methods
	using more useful methodologies now common in other educational fields and accepting that teaching without evaluation is no guarantee of learning.

Crossing the boundary will be a challenge to many of us. The next section looks at a model of professional action which will facilitate such changes in our praxis

Understanding the actions of professionals

For many years education reform has been imposed on teachers in many parts of the world. Teachers have had little or no voice in the changes which have been foisted on them. Overload, burnout, demoralisation, poor implementation and a rush for early retirement have been widespread consequences. Positive education change is needed more than ever, but in a way that puts teachers in the vanguard of it, rather than making them its marginalised victims. It is time to bring teachers back in and look at educational change with more generous eyes [2].

Much professional development to date assumes the 'teacher as technician' model which denies the developmental needs of the professional teacher. The review of Nofke & Zeichner [3] revealed an impressive number of developmental outcomes related to teachers analysing their own practice.

The purpose of the first part of this paper is to provide an analytical framework for the study of the interaction between knowledge, values and practice within the professional development process. The adopted perspective substitutes a 'moral order' for the 'causal-technical order' within which much teacher development is traditionally set ([4], p. 222). The essential features of Butler's model of human

action are displayed in Fig. 1 and places the elements within two background contexts: the self in relationship with the social context.
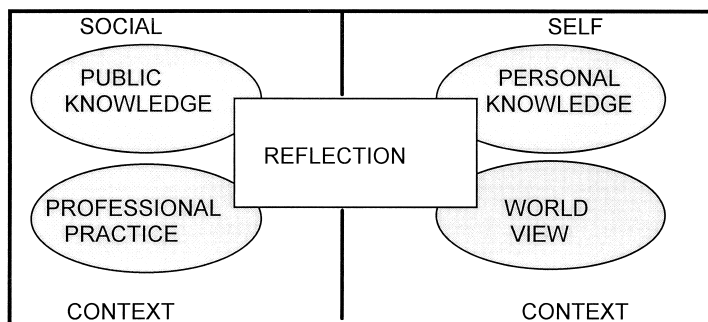
Fig. 1 The elements of Butler's [4] model of human action.

Reflection is at the centre of the model and is the open, active communication channel between the social context and the inner self. Reflection is an evaluative dialogue that enriches the self and enhances professional practice. Reflection can act as a forum for the decision making that results in considered action in the teaching context.

> It is hard work to hold these internal debates. They require time and energy just to conduct them. And if we take them seriouslywe usually find ourselves being urged to take the more difficult path, the path of more effort rather than less. ([5], p. 272)

Public knowledge includes all that the teachers interact with in the form of theories, formal knowledge, policy directives, research results, hints and folk lore, community and student expectations. Public knowledge is a very visible and clamorous component of this model. It attempts to mould and control the professional practice of the teacher.

Professional practice of the teacher is the human action itself. This occurs in the social context when teachers have to make decisions and act according to their responsibilities. This informed action requires the teacher to understand the salient features of the situation. The model assumes that professional practice is more deeply expressive of the self than of external public knowledge.

World view is the individuals own way of looking at the world derived from tradition and culture and is therefore historical and contextual. World views contain a mixture of rational and irrational beliefs, some contradictory assumptions, and a tablet of values and rules that the self holds as true at this stage of its development. The world view provides stability but to be effective must be continuously revised through careful and detailed self-examination.

Personal practical knowledge is a store of knowledge and understanding attained through lived experience and is enriched through wider and more vivid experiences and can be transformed by paradigm shifts in understanding. This conscious and unconscious personal knowing is the 'tacit knowledge' that has been shown to exert a powerful influence on performance. The personal practical knowledge that is required for personal and professional development cannot be extended systematically and justification of one's personal practical knowledge must appeal to courts other than the courts of reason or strict rules or method. Rather the justification is historical or contextual; the knowledge is excellent now for this context, it is designed for the how and the now.

The personal practical knowledge that is gained is about trusting the self to perform, to trust what one already knows, to be authentic in all ways, to value and use that which has been derived from action and led to fruitful action.

The teachers, singly and together, are presumed to be the practitioners who measure the effectiveness of their practice and use proactive as well as reactive interventions. Butler claims that professional development must satisfy the following relationship:

rate of professional change $\geq$ rate of change in the teaching context

This then provides a brief introduction to the model of teacher agency that informs the remainder of

this paper on teacher professional development. Two well-known characteristics of human action are: the certainty of human action is never equal to the immediacy of action; and that human action always gives rise to unintended consequences. Both of these features offer opportunities for teachers to learn from undertaking deliberate and carefully designed praxis. The choice of what to do is the beginning rather than the end of the processes of justification and reflection.

DIMENSIONS OF PROFESSIONAL ACTION: CHOICES AND CONSEQUENCES

This section introduces 12 pedagogical dimensions to analyse the professional actions of teachers. These pedagogical dimensions include such influences as philosophy (world view), teacher roles (personal practical knowledge) and learner control (teacher praxis) and course goals (public knowledge). These dimensions draw on the work of Reeves [6], Wilkinson [7] and Cooley & Lohnes [8].

Dimension 1—epistemology

Epistemology is concerned with theories about the nature of knowledge (Scheme 1).

Epistemology

Objectivism ←————————————————————→ Constructivism
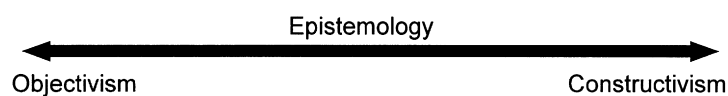
Scheme 1 Epistemological dimension.

Objectivist epistemology encompasses the following facets:

- knowledge exists separate from knowing,
- reality exists regardless of the existence of sentient beings,
- humans acquire knowledge in an objective manner through the senses,
- learning consists of acquiring truth, and
- learning can be measured precisely with tests.

Constructivist epistemology (cf. [9]) encompasses a different set of facets:

- knowledge does not exist outside the bodies and minds of human beings,
- although reality exists independently, what we know of it is individually constructed,
- humans construct knowledge subjectively based on prior experience and metacognitive processing or reflection,
- learning is acquiring viable assertions or strategies that meet one's objectives, and
- at best, learning can be estimated through observations and dialogue.

If teachers lean toward an objectivist epistemology they will seek to establish a definitive structure of knowledge for a given domain based upon the advice of the most widely accepted experts in a field. For example, in chemistry education, they will seek to transmit to students the immutable laws of any given field.

Advocates of constructivist epistemology, on the other hand, will be much more concerned with assuring that the content reflects the complete spectrum of views of a given domain, ranging from the traditional academic perspectives to the views of the most radical 'fringe.' Above all else, constructivist epistemology calls for multiplicity of perspective's so that learners have a full range of options from which to construct there own knowledge. In chemistry education, constructivists would provide students with opportunities to rediscover the currently accepted theories as well as rival theories that may eventually replace the current positions. They would provide coaching or scaffolding to assist students in their 'discovery'.

Dimension 2—pedagogical philosophy

Pedagogical Philosophy

Instructivist ⟵⟶ Constructivist
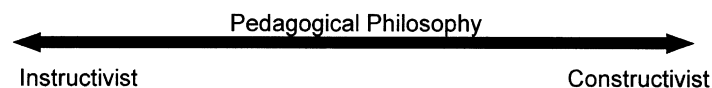
Scheme 2 Pedagogical philosophy dimension.

Instructivists stress the importance of goals and objectives that exist apart from the learner. These goals and objectives are drawn from the discipline of chemistry. Once goals and objectives are delineated, they are sequenced into learning hierarchies, generally representing a progression from lower to higher order of learning. Then, direct instruction is designed to address each of the objectives in the hierarchy, often employing instructional strategies derived from behavioural psychology. Relatively, little emphasis is put on the learner per se who is usually viewed as a passive recipient of instruction.

Alternatively, constructivists emphasise the primacy of the learners intentions, experience, and metacognitive strategies. The constructivist view of learning involves individual constructions of knowledge. In this view, learners attain a state of equilibrium through reconstruction of concepts, schema, mental models, and other cognitive structures in the face of new information and experience that may conflict with earlier constructions. A major role of constructivist pedagogy is to assure that the learning environment is as rich as possible. Major emphasis is placed on identifying the unique interests, styles, motivations, and capabilities so that learning environments can be tailored to them.

Dimension 3—underlying psychology

Underlying Psychology

Behavioural ⟵⟶ Cognitive
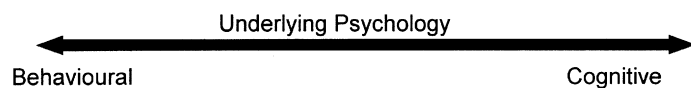
Scheme 3 Underlying psychology dimension.

According to classical behavioural psychology, the important factors of learning are not internal states that may or may not exist, but behaviour that can be directly observed. Teaching consists primarily of the shaping of desirable behaviours through the scientific arrangement of stimuli, responses, feedback, reinforcement, and other contingencies. For example, many CBT programs use instructional models directly derived from behavioural psychology. First, a stimulus is provided, often in a form of short presentation of content. Second a response is demanded, often in a form of a question. Third, feedback is given as to the accuracy of the response. Fourth, positive reinforcement is given for accurate responses. Fifth, inaccurate responses result in either a repetition of the original stimulus or a somewhat modified (often simpler) version of it, and the cycle begins again.

Cognitive psychology places much more emphasis on internal mental states than behavioural psychology. Cognitive psychologists recognise that a wide variety of learning strategies may have to be employed in any given learning setting depending upon the type of knowledge or skills to be constructed. Student IQ has been discarded as a predictor of educational success.

Dimension 4—goal orientation

Goal Orientation

Sharply-focused ⟵⟶ Unfocused
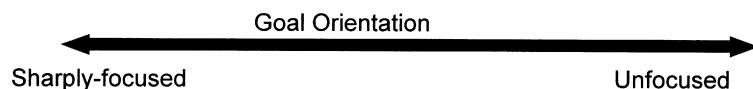
Scheme 4 Goal orientation dimension.

With the advent of Bloom's Taxonomy of Educational Objectives, goals and objectives with their associated performance indicators have 'sharply focused' the outcomes of the recent curriculum documents. This move to outcomes-based curriculum designs contrasts with curricula which are essentially input-based and describe more directly the desirable learning experiences which students should experience.

Dimension 5—sequencing learning

The reductionist view contrasts remarkably with the constructivist. In the former, learning to accomplish a task (e.g. troubleshoot electronic components) requires that all the components of the task be mastered independently before they can be assembled into the final performance. In the latter, instructional sequencing based upon a constructivist view might put novice learners in a realistic context requiring troubleshooting, in which scaffolding and coaching would be introduced as needed by individual learners. Scheme 5 presents a continuum of instructional sequencing views ranging from reductionist to constructivist.

Sequencing Learning

Reductionist   Constructivist
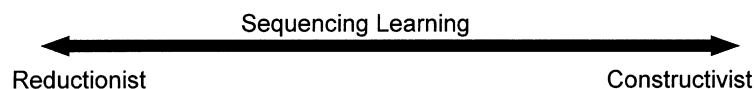
Scheme 5 Instructional sequencing dimension.

Dimension 6—experiential validity

A major criticism of much of our current dominant pedagogical methods is that they are too abstract, removed as they are from 'real world' experience. Scheme 6 illustrates an experiential validity continuum ranging from abstract to concrete.

Experiential Validity

Abstract   Concrete
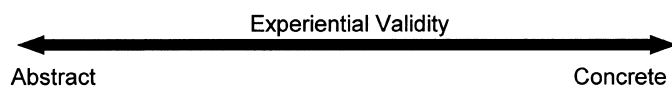
Scheme 6 Experiential validity dimension.

A major concern for teachers is the degree to which classroom learning transfers to external situations in which the application of knowledge, skills, and attitudes is appropriate. If knowledge is learned in a context, will it be used in that and similar contexts? This is especially important in training for the work place such as a laboratory.

Does traditional teaching abstract knowledge and skills from their uses in the world? In apprenticeship or internship learning, knowledge and skills are seen as instrumental to accomplishment of meaningful tasks. The apprenticeship model is based on modeling, coaching, scaffolding, articulation, reflection, and exploration as opposed to didactic teaching strategies such as telling and correcting.

Dimension 7—role of teachers

Role of Teachers

Teacher-Proof Materials   Equalitarian Facilitator
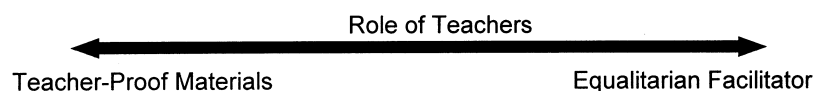
Scheme 7 Role of teachers dimension.

The production of the alphabet curricula such as CHEM Study in the 1960s and 1970s represented the dominance of professional chemists in designing the learning sequence in minute detail. This approach provided for little teacher decision making. In more recent times the development of resource materials such as ChemCom (USA) and Salter's Advanced Chemistry (UK) and Logical Connections (Australia) have provided for much more teacher autonomy as the 'context to concept' approach requires a high degree of teacher decision making based on students' 'need to know'.

Dimension 8—value of errors

The old maxim that 'experience is the best teacher' reflects a belief that we learn much in life through trial and error. Although this approach may be inefficient and even dangerous in some contexts, experiential learning is highly valued simply because it provides opportunities for us to 'learn from our mistakes.' On the other hand, some educational theorists, especially proponents of programmed instruction, have maintained that ideal learning involves no errors. Instead, they attempt to arrange the contingencies of

instruction in such a way that learners can only make correct responses. Scheme 8 presents a continuum of error values ranging from errorless learning to learning from experience.

Value of Errors

Errorless Learning — Learning from Experience
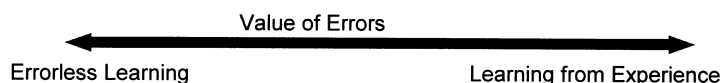
**Scheme 8** Value of errors dimension.

Dimension 9—motivation

Motivation is a primary factor in most learning models. The major challenge is to provide a meaningful learning context that supports intrinsically motivating and self-regulated learning (Scheme 9).

Motivation

Extrinsic — Intrinsic
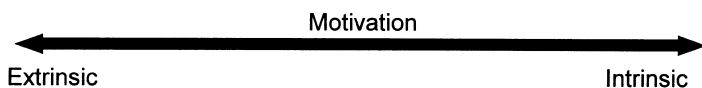
Scheme 9 Motivation dimension.

Intrinsically motivated learning is very elusive regardless of the delivery system, but virtually every new approach to come along promises to be more motivating than any that have come before. For example, interactive multimedia (IMM) is the latest style of interactive learning system that is to motivate learners automatically, simply because of the integration of music, voice, still pictures, text, animation, motion video, and a friendly interface on a computer screen.

Dimension 10—accommodation of individual differences

Accommodation of Individual Differences

Non-existent — Multi-faceted
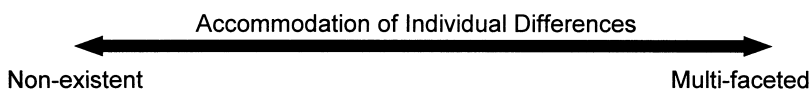
Scheme 10 Accommodation of individual differences dimension.

Learning is a function of the learner, the content to be learned, and the features of the learning setting. Most theoretical models of learning treat individual differences among learners as the major predictor of differential learning outcomes. In most education contexts, our learners will not be homogeneous in terms of aptitudes, prerequisite knowledge, motivation, experience, learning styles, eye–hand coordination, and so forth. Therefore, we must endeavour to provide scaffolding, cognitive bootstrapping, and other types of metacognitive support to promote learning [10].

Dimension 11—learner control

Learner Control

Non-existent — Unrestricted
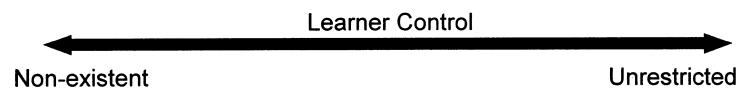
Scheme 11 Learner control dimension.

Learner control refers to the options in curriculum design that allow learners to make decisions about what sections to study and/or what paths to follow through interactive material. The popular wisdom is that learner control makes learning settings more effective by individualising the teaching and making it more motivating, but all too often experimental studies have led to no significant results in terms of the predicted main effects (cf. [11–13]).

Learner control is a very complex issue. The finding that learner control of context for example is effective in one setting and another finding that learner control of the amount of review is effective in another setting provides little basis for linking these two types of learner control into a meaningful prescription for curriculum design, e.g. structure.

Dimension 12—cooperative learning

Support for the value of cooperative learning is growing throughout education and training circles [14]. Curricula can be designed to thwart or promote cooperative learning. Scheme 12 illustrates the cooperative learning dimension ranging from a complete lack of support for cooperative learning to the inclusion of cooperative learning as an integral part of teaching.

Cooperative Learning

Unsupported   Integral
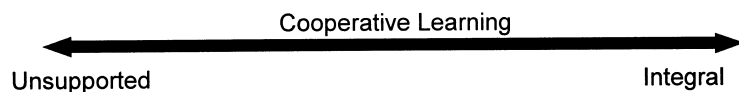
Scheme 12 Cooperative learning dimension.

Cooperative learning refers to teaching methods in which learners work together in pairs or small group to accomplish shared goals [15]. Johnson & Johnson [16] and Slavin [17] present evidence that when learning settings are structured to allow cooperative learning, learners benefit both intellectually and socially.

SHAPING UP: WHAT WORKS AND WHAT DOESN'T

The two previous sections have highlighted some of the dimensions of human action and their interrelationships which can help explain the professional practice of teachers. Again we need to remind ourself that for chemistry classrooms to the different professional development opportunities must ensure that:

rate of professional change $\geq$ rate of change in the teaching context.

Why reforms fail

According to Fullan & Miles [18], schools and districts are overloaded with problems and solutions that do not work. It is not a question of lack of innovation, but the enormous overload of fragmented, uncoordinated, and ephemeral attempts at change. They outline seven reasons why typical approaches are not successful:

Faulty maps of change. Everyone in school reform from teachers and parents through to state department officials has a personal map of how change proceeds and these constructs are expressed as propositions. e.g. 'Every school is unique'; 'Full participation of everyone involved in a change is essential'; and 'Mandate change because people won't do it otherwise'. People act on their maps but these don't provide reliable guidance. Maps are necessary but they need to be a valid representation of the territory.

Complex problems. Solutions to questions of reform are not simple or even known in many cases. First order changes such as curriculum design, teaching and learning and assessment and their interrelationships are daunting. Second order changes in school cultures, teacher/student relationships and expectations of the system are even more daunting. Any approach to change must acknowledge that we may not know all the answers but is conducive to developing solutions as we go along and it sustains the commitment to stay with the problem until we get somewhere.

Symbols over substance. Education reform is as much a political reform as an educational process. Reform often fails because politics favours symbols over substance. Substantial change in practice requires lots of hard and smart work on the ground which is not the strong point of political players. Symbols are essential for galvanising visions and acquiring resources out of effective reform requires both if we are to eliminate the predisposition to be sceptical about all reforms.

Superficial solutions. A bane of reform is faddism. Innovation and reform are big business, politically and economically. The temptation to take the quick fix, to be trendy, and to react uncritically leads to short lived superficial solutions are heading in the right direction, hasty implementation leads to failure.

Misunderstanding resistance. Change involves individual attitudes and behaviours but they need to be understood as natural responses to innovation not misunderstood as resistance. Any significant change involves a period of intense personal and organisational learning and problem solving. People need support not displays of impatience.

Attrition of pockets of success. Successful reform requires enormous effort on the part of individuals, an effort which may not be sustainable. What happens as a results of decisions outside of the school e.g. transfers of staff and changes in district policy can reverse any gains. Innovative schools require on going support to remain innovative.

Misuse of knowledge about the change process. Reform is systemic and action based on knowledge must also be systemic.

Statements such as 'lots of inservice is necessary' and 'vision and leadership are critical' are half truths and if taken literally can be misused.

Towards success

The following propositions are representative of current knowledge about reform of educational systems. These propositions will need to be incorporated into the thinking and actions of everyone associated with bringing about change [19].

Change is a journey not a blueprint. Rational planning models of complex social change do not work. Rather it is a guided journey. Do, then plan. and do and plan some more. Strategy is viewed as a flexible tool, rather than a semipermanent expansion of the mission [20].

Change is learning loaded with uncertainty. Anxiety and difficulties are intrinsic to all successful change. Innovation represents new personal meaning and new learning. Conditions that support learning must be a part of any change effort because ownership of reform cannot be achieved in advance of learning something new.

Problems represent opportunities. Problems become opportunities when by immersing ourselves in the process we allow a creative solution to surface. Success in school reform efforts is more likely when problems are treated as natural and expected phenomena rather than as opportunities to blame others and to be defensive about ourselves.

Resources are the appetites of change. Change requires additional resources for training, for teacher relief, for new materials and for time. Time is energy and time is money. Good resourcing abjures any false pride about self-sufficiency and it requires nous to go outside the normal framework in reallocating available resources.

Management of change requires the power to do so. District officers need to be engaged in a collaborative and supportive way and should place few bureaucratic restrictions in the path of reform. Development of the culture of a school requires the power to manage the change at the school level. Complex problems cannot be solve at a distance; schools must have an interactive and negotiated relationships with their wider environments.

Change is systemic. Reform must focus on the curriculum, teacher development, community and school support systems simultaneously and must not just concentrate on structure, policy and regulations. Deeper issues of the culture of the school need to be addressed. The emphasis should be on the new cultural norms for collaborative work and on the pursuit of continuous improvement.

Large-scale change is implemented locally. Change cannot be achieved from a distance. The previous propositions will only have any meaning if there is local implementation by everyday teachers, principals, students and parents. Living out these propositions will mean that change will become explicit for all the stakeholders and that our knowledge of successful change processes will grow.

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