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Exploring the complementarities between complexity and action research: The story of *Technology Together*

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This paper takes up an ongoing dialogue in the educational literature regarding the relationship between complexity theories and action research. Recognising the contributions of Radford (2007) and Davis and Sumara (2005b; 2009) and building on arguments made previously (Phelps & Hase, 2002) this paper argues that there *are* multiple synergies between complexity and action research, and that action research can be a valuable and congruent meta-methodology for those researching from complexity-based perspectives. The paper illustrates these arguments through the example of a large action research initiative, *Technology Together*, which aimed to investigate the metacognitive influences on teachers' use of information and communications technology (ICT) and the implications of these for teacher professional development within a whole-school context.

Introduction

In June 2007 an article by Mike Radford from Canterbury Christ Church University College, UK, appeared in the *Cambridge Journal of Education*, challenging the relevance and connections between action research and complexity theory. These ideas were also presented at the *Complexity Science and Educational Research Conference* that same year. Radford's arguments form a critique of a particular 'type' of action research, an approach which he argues is promoted through UK Government policy (Radford, 2007a) and employed by the Teacher Development Agency. This approach, Radford suggests, has a strong focus on 'best practice scholarship' conceived within a standards-based and 'improvement' agenda (Radford, 2007b).

Radford's arguments build on an understanding of action research, drawn in significant part from Hopkins (2002, cited in Radford, 2007a), which privileges an interpretation of practitioner action research as driven by hypothesis testing, reductionism, technical control and assumptions that improvement is a central objective of the action research. These approaches, Radford claims, "assume that educational situations and events can be considered as bounded systems, subject to reductive analysis, that specific actions can be taken and formally evaluated within the context of a series of linear

stages or cycles” (p.263). Such “technicist and reductive approaches”, he points out, have been critiqued in action research literature but, he argues, “there is nothing implicit in the action research model... that resists this kind of approach” (p.264). Radford develops the argument further:

...to the extent that action research may be seen (a) to neglect the complexity of educational situations; and (b) to adopt a methodological tendency towards a deconstruction/reductionist paradigm, it is unlikely that it will meet the claims that are made for it in terms either of controlled improvement or the emancipation and empowerment of the practitioner (Radford, 2007a).

While recognising that these arguments may have some basis within particular socio-political educational research contexts, this paper argues that action research provides a highly valuable, consistent and defensible approach to educational research and can readily accommodate the key tenets of complexity theory. Indeed, as Sumara and Davis (2009) describe it, there is a ‘deep complementarity’ between complexity science and action research. The paper will build on ideas previously proposed (Davis & Sumara, 2005b; Phelps & Hase, 2002; Sumara & Davis, 2009) and highlight examples from a recent project to argue that action research *can* provide an appropriate meta-methodology for educational practitioners who recognise and embrace the fundamental tenets of complexity theory. Furthermore, it is proposed that action research can be an effective vehicle for challenging and supporting teachers, schools and education systems to engage with notions of non-linearity and emergence and to embrace complexity-informed perspectives on education.

The discussion will draw on the example of a three-year action research project, *Technology Together*, to illustrate the complementary potential between action research and complexity theory. The *Technology Together* project will first be briefly introduced and the particular action research approach underpinning it will be defined and explained. The paper will then discuss a number of assertions about action research that position it as consistent and compatible with core understandings associated with complexity theories, highlighting how these were integrated into the *Technology Together* project.

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Introducing the *Technology Together* initiative

Technology Together was a collaborative action research and development initiative of the Catholic Education Office, Lismore Diocese and Southern Cross University, supported by funding for 2004-2007 from the Australian Research Council (ARC). Building on earlier research which highlighted the limitations of traditional approaches to professional development for teachers in ICT (for example, Ertmer, Gopalakrishnan, & Ross, 2001; Ertmer, Ottenbreit-Leftwich, & York, 2006-7; Ropp, 1998; Ross, Johnson, & Ertmer, 2002; Snoeyink & Ertmer, 2001; Tearle, 2003), *Technology Together* sought to investigate the effectiveness of a metacognitive approach (one focused on teachers’ attitudes, values and beliefs) in supporting teachers’ learning with and about ICT. The metacognitive approach had been developed through earlier research with individual pre-service and practicing teachers (Phelps, 2002; Phelps, 2005; Phelps, 2007; Phelps & Ellis, 2002a, 2002b; Phelps, Graham, & Kerr, 2004). *Technology Together*, as an extended action research initiative, aimed specifically to refine this approach for a whole-school professional development and culture change context.

Technology Together, and the metacognitive approach more generally, has a clear focus on experiential learning, encouraging teachers to implement initiatives in their classrooms, thus resulting in immediate learning outcomes for both themselves and their students. In a practical sense, the project

also aimed to: increase teacher confidence in using computers; increase teacher integration of ICT in teaching; support teachers to implement curriculum; diversify teachers' ideas and knowledge about how they might integrate ICT and increase teacher dialogue within the whole-school context regarding ICT. *Technology Together* provided strategies to support individual teachers and whole schools in goal-setting processes whereby everyone involved identified and focused on initiatives that were relevant to their own needs. It also supported schools to implement a range of strategies for supporting individuals and the school community throughout the year; strategies which were consistent with the metacognitive approach, and which built supportive school cultures through reflection and discussion.

The authors of this paper were the university-based facilitators of *Technology Together*, and they played key roles as critical friends and overall project coordinators, working alongside the fifty school-based project facilitators (known as 'Companion Mentors') from sixteen schools involved in the research.

Details about *Technology Together* and the findings from the research, have been documented elsewhere (Phelps & Graham, 2007; Phelps & Graham, 2008; Phelps, Graham, Brennan, & Carrigan, 2006; Phelps, Graham, & Thornton, 2006; Phelps, Graham, Watts, & O'Brien, 2006). It is thus not the intention of this paper to describe the research in detail. Rather, this paper will point to aspects of the project that indicate why action research can comfortably coexist with understandings from complexity theory. Before doing so, however, it is important to define action research and particularly to describe how this conceptualisation manifested in the *Technology Together* project.

Exploring understandings of action research

As foreshadowed in this paper's introduction, definitions, interpretations and the implementation of action research can be as diverse and variant as those embracing and participating in it. Clearly, the nature, purpose, goals, processes and outcomes of any research will be shaped by the ontology, epistemologies, philosophies, beliefs and assumptions of those engaging in it as well as the socio-political contexts in which it is conceived, developed, conducted and (perhaps) funded. The existence of particular 'schools' and 'allegiances' within the action research community is highlighted by Reason and Bradbury (2008) who attempt, nonetheless, to provide a working definition; that action research is 'a participatory, democratic process concerned with developing practical knowing in the pursuit of worthwhile human purposes, grounded in a participatory worldview' (p.1).

Historically there has been, at times, a degree of methodological prejudice levelled against action research (for instance, by research funding bodies) and consequentially this may have tended to lead educational authorities and organisations to privilege certain 'forms' of action research over others – in particular, the more 'scientific/technological' forms described by Radford (2007a, 2007b) as favoured within his particular context. However, these forms are not those espoused from a deeper understanding of the tenets of action research itself as described, for example, by Reason and Bradbury (2008), Sumara and Carson (1997) or Whitehead (1989). In fact, these descriptions are quite at odds with contemporary discussions and would not seem to accord with the forms of action research promoted and supported within the Australian education context, where a number of national initiatives in recent years have encouraged and funded school-based and teacher driven action research initiatives (for example the *Australian Quality Teaching Program* and the earlier *Innovative Links* program). These initiatives were far less focused on hypothesis formulation and testing, or the need for generalisable findings, than on

fostering teacher learning, dialogue and enhanced understandings about issues encountered by teachers in their everyday practice.

It is not our intention to provide further definitions or explanations of action research, but rather to illustrate, through a description and exploration of one particular action research initiative, how complexity theory's foundational ideas *can* be embraced within action research processes and, similarly, how action research itself can support complexity-informed research. We will, however, acknowledge that action research has already been extensively theorised in relation to systems theories and systems thinking (see for example Flood, 2001; Levin, 1994) and that there is a close relational lineage between complexity theories and systems thinking. In this paper, however, we have particularly chosen to focus on the theories commonly associated with the popularly termed 'complexity science'.

How 'we' conceived action research in *Technology Together*: Setting the scene

As an action research project *Technology Together* involved two macro-cycles conducted over two years, with 7 schools participating in 2005 and a different 9 schools participating in 2006. Of these 16 schools, 14 were primary schools and 2 were secondary schools. Each school engaged in three micro-cycles (one per term for three terms), with learning from schools involved in 2005 being conveyed to, and built on, by schools in 2006. Micro-cycles involved schools in planning, implementing and evaluating a range of initiatives and strategies considered consistent with the metacognitive approach. Of course, in reality, the cycles were more 'messy' and fluid than this but were interspersed by visits from University staff (the authors of this paper), providing explicit opportunities to reflect and re-group on activities occurring within each school term.

Participants worked closely with us to develop, implement and refine metacognitive approaches to teachers' ICT learning within their school contexts [and here we acknowledge Sumara and Davis's (2009) problematising of the term 'context']. The processes were facilitated in schools by key staff, referred to as Companion Mentors (CMs), who also played a role as key researchers. The research incorporated a wide range of data, including pre- and post-intervention surveys, workshop evaluations, planning and implementation documents, journals completed by teachers, notes from staff discussions, samples of work, observations and critical reflections, as well as interim and final reports prepared by participating schools. A focus was placed on triangulation and member-checking of all data, with an emphasis on maintaining notions of 'teacher voice'. A Reconnector Workshop, held in 2007, with representatives from most schools, shared and discussed findings and recommendations for the final project report.

What might be said, then, about the approach to action research embodied in *Technology Together* was that there was no firm hypothesis being 'tested', and no formulaic approach to what schools might do or try as part of the process. While we were certainly aiming to support collective development and change within schools, there was no notion of 'standards' or 'best practice' underlying our activities. The research was not causally based but rather characterised by a spirit of collective learning. Indeed the metacognitive approach underpinning the project was itself theoretically consistent with complexity-based thinking, as has been argued elsewhere (Phelps, Hase, & Ellis, 2005). The focus of the following sections of this paper, then, will be more on the research *process* rather than the content and focus of the project.

Connection between action research and complexity theories

In this section we propose a number of assertions about action research and how it potentially complements core understandings bound up with complexity theories. In particular, these assertions are that:

- Action research accepts the inherent unpredictability of *open, non-linear systems*
- Action research is consistent with notions of *adaptation to environment*
- Action research can evoke *processes of bifurcation*
- *Agent interaction* is central in action research
- Action researchers are interested in *feedforward and feedback*
- Action research embraces *reflective processes*
- Action researchers are interested in '*exceptions*'

Clearly, there are issues in attempting to generalise and/or make broad assumptions about action research. As previously stated, much depends on the intent and approach of the action researchers themselves. While making these assertions, based on our own reading, experiences and observations in relation to action research and complexity theories, we do not intend to universalise or to imply that these assertions stand for *all* action research or action researchers. Rather, our aim is to posit an alternative to the views presented by Radford regarding what action research 'is' and 'does' – perceptions which are at odds with those emerging from our own observations of, and experiences with, action research.

Action research accepts the inherent unpredictability of open, non-linear systems

As Davis and Sumara (2005b, p.455) describe, 'the goal of complexity is neither reduction nor certainty, but enhanced understandings of the common features of complex systems, while preserving the particularities of those systems'. We would argue that most action researchers *do* accept the inherent unpredictability stemming from the complex and non-linear social settings within which they are normally situated. Educational action research, in our experience, is rarely about establishing causal connections (i.e. assuming certainty and prediction are possible) nor about controlling variables or testing hypotheses. Most action researchers do, through the pragmatic nature of their action, acknowledge that the systems in which they work are irreducibly complex and that they cannot hope to understand or control all the factors impacting on their social context. This does not, however, imply that they are rendered inactive, passive or helpless in the face of such complexity. Action researchers, rather, take a pro-active stance in working with, and learning from, this unpredictability. They do so, generally, without a need for reductionism. The much discussed 'mess' which often characterises action research is an expression of this recognition. Rather than trying to predict the outcomes of interventions, action researchers are perhaps more accurately involved in evoking, welcoming and better understanding change processes, without needing to try and establish simple causal connections. In the words of Wadsworth (1998, p.2), for action researchers 'the future is made, not predicted'.

Notions of generalisation are understood quite differently within action research contexts. Action researchers tend to reject ideas that generalisable solutions can fit multiple situations but rather work with alternate understandings where ideas concerning generalisation (perhaps relevance and applicability might be more appropriate terms) rest with those who participate or read about a study and the degree to which it 'resonates' with aspects of their own context (Dick & Swepson, 1994). In this sense, knowledge generation is more of the form 'what worked for us in our particular context' and is therefore normally accompanied by rich descriptions of contextual information.

Action researchers also recognise that the very process of engaging in this kind of research necessarily changes the nature of these processes (Kemmis & McTaggart, 2000), signalling not only a recognition of inherent unpredictability but also a consistency with the ontological underpinnings of complexity theories.

Within the *Technology Together* project this recognition of inherent unpredictability was implicit from the formulation of the research focus, to methodological design, implementation, data analysis and interpretation. The research did not set out to establish a definitive set of steps which were likely to work in all schools for all teachers. Nor was it a goal to establish linear causal connections between specific actions or processes implemented and outcomes observed. As university-based researchers, we did not attempt to predict or to impose what we might expect appropriate approaches to be. Rather we perceived our role as sharing with participants our own assumptions, beliefs and observations about the processes of teacher adaptation to ICT and to learn with, and from, the participants as ideas 'played out' in practice. The 'metacognitive approach' underpinning the research was not presented for participants as a testable process but rather as a general orientation for focusing computer professional development around teachers' values, attitudes, beliefs and learning approaches and of working with teachers to foster computer capability, as opposed to a more limited and defined notion of computer competence (Phelps, Graham, Watts, et al., 2006; Phelps, et al., 2005). From this, the participants themselves sought to pursue strategies and approaches which *they* felt would 'work' within their own school context.

This was not to say that changes in teachers' values, attitudes, beliefs and practices with ICT were not of central interest, but rather that simple causal connections to specific actions were avoided and contextualised. Every teacher, every class and every school context was acknowledged as distinctive and the processes which were implemented at individual and school level were driven by the schools themselves. It was not individual actions which were viewed as potentially influencing change, but rather the complex interplay of identified and unidentified factors. While data was collected to document change, interpretations of what contributed to these changes remained embedded in the narratives and interpretations of the participants themselves.

Action research is consistent with notions of adaptation to environment

Within complexity theory, development and change is viewed as natural and evolutionary – neither imposed nor random (Doll, 1997-8). Change is associated with adaptation and, in particular, learning is viewed as adaptation to environment based on experience. This learning is not just an individual but a shared experience of interaction, alignment and organisation within and between agents (individuals or collectives) in order to create new and collective schemas (understandings, assumptions or practices).

Whilst the language of change is certainly an integral part of action research, this is not necessarily to imply that change moves unproblematically in the direction of 'best practice' or 'desired

destination'. Rather, action research can be seen as facilitating informed emergence - collective recognition of the need to continually learn and adapt to changing environments. Action research initiatives are, by nature, very much about creating conditions for new possibilities to emerge. Whether these changes are conceived as 'improvements' will, according to Radford, be relative and subjective, with notions of empowerment and emancipation in need of critique. However, a complexity-based perspective on action research is less troubled by making external judgements about what may or may not constitute 'improvement' but rather focuses on the nature of the interactions between the 'component parts' and the ways the system organises and interacts to enact this change. Emergent structures are not outcomes in themselves but rather influence future events, making possible the evolution of qualitatively different kinds of systems (Mihata, 1997). In other words, action research is more concerned with the processes involved in change and learning and how they might support participants to better adapt to their environment and circumstances.

Furthermore, as alluded to in the previous section, the emergence of new ideas and practices is not conceived in complexity as linear and predicatable. Thus, from a complexity perspective, any outcome of an action research initiative (if there can be said to be a single or identifiable 'outcome') will be unpredictable. In our experiences of action research, participants aren't attempting or expecting to 'predict' what these emerging ideas or practices might be, but rather would 'go with the flow'. Again, to draw on Sumara and Davis's discussion of complexity and action research, 'life and learning are understood in terms of explorations of ever-evolving landscapes of possibility and of selecting (not necessarily consciously or deliberately) actions that are adequate to situations' (Davis & Sumara, 2005b, p.457).

Technology Together was very explicitly about adaptation to environment in both its content and process. Implicit in the underpinning distinction between computer 'competence' and computer 'capability' was an opening up of dialogue between participants about the need to continue to learn as computer technology developed and changed, together with the importance of learning approaches which were well adapted to this ever-evolving environment. Companion Mentors worked with teachers to self-examine their own assumptions, beliefs and practices concerning computer use and learning and whether these were enabling or constraining their ability to adapt to the increased expectations on them to integrate ICT into their teaching practice.

The action research process which shaped *Technology Together* was also explicitly open to being adapted to the culture and context of each school. Each school approached the challenge in different ways depending on a wide range of factors including leadership styles, school size, background and interest of the staff, history of previous ICT professional development initiatives and hardware and software resources. Some focused on building upon their cohesive and supportive school culture through whole-school initiatives (such as all children producing digital portraits for exhibition and sale at the school fête) while others allowed mentoring relationships between staff to evolve based on existing histories and current cultures (such that in some schools teachers preferred 'like-to-like' partnerships for learning, rather than 'expert/novice' structures).

In this sense, action research enabled a flexible and responsive approach to data collection which would not have been possible using other research methodologies, particularly those that seek to control variables. *Technology Together* thus facilitated participants' adaptation of the research process to their environment, as well as adapting the learning gained in their unique context.

Action research can evoke processes of bifurcation

Bifurcation, or phase transition, is the term used by complexity theorists to describe the branching of phenomena seen during chaotic episodes (Price, 1997). Often referred to as 'tipping points', phase transitions occur when a system moves from one form of stability to another, prompted by conditions which may or may not be 'known'. In other words, bifurcation usually results in new but more complex stabilities. As described by Davis and Sumara (2005b, p.455), 'coherent collective behaviours and characters emerge in the activities and interactivities of individual agents. Such self-organized forms can spontaneously arise and evolve without leaders, goals or plans'. The term *autopoiesis* is used in complexity theory to refer to such patterns of self-generating, self-amplifying and self-maintaining systems. The notion of autopoiesis may be of value to action researchers in furthering their understandings of the contexts in which they work, and in particular the nature of the change processes they are involved in. It has been argued elsewhere (Phelps & Hase, 2002) that the concept of deliberately introducing 'noise' into a system to see what happens (Lissack, 1999) is consistent with the action/observation phases of action research. In this context 'noise' refers to a disturbance of the system as a result of (usually) unforeseen causes, which might include new information, ideas or actions. The 'action' in action research might be conceived as an energy input, which in some instances prompts a state of non-equilibrium. From this, new possibilities, and perhaps new stabilities, emerge. Thus, action research might be considered the vehicle to both promote and study such processes.

Another concept explored through complexity theories is that of 'redundancy'. In simplified terms, a level of diversity among and between agents enables novel responses, thus facilitating evolutionary possibilities. Such redundancy can prompt both gradual emergence or more rapid and radical bifurcation.

In *Technology Together* understandings of the action research process were strongly informed by the ideas of bifurcation, autopoiesis and redundancy. To provide some examples, the research was grounded in a differentiation between computer learning for 'competence' and computer learning for 'capability'. This model, described in detail elsewhere (Phelps, et al., 2005), conceptualises facilitation of computer learning as prompting either individuals or collectives to move from a more constrained learning path directed toward specific and defined skills and knowledge ('competency') toward a more emergent learning path of 'capability' – consistent with ideas of 'expanding the space of the possible' (Davis & Sumara, 2005b). *Technology Together* sought to enable circumstances which were likely to assist transitions (bifurcations) from the 'competency' path to the 'capability' path. The action research documented such bifurcations as occurring in response to particular happenings. Within this context we were able to acknowledge that what one teacher learns (and perhaps more importantly *how* she/he learns it) can have an enormous impact on others – both positive and negative – deliberate and incidental. For example, a realisation by a novice teacher that they were able to learn a computer skill independently through exploratory processes, and their subsequent sharing of this 'a-ha' with others, could have a quite profound influence on how a school community approached teacher professional development. Such an approach was consistent with mentors exploring ways of 'occasioning' learning (Davis & Sumara, 2005b) with and for their colleagues – rather than assuming traditional 'training' mentalities. It was also fostered through active promotion of engagement in reflective dialogue and sharing of experiences - both successes and frustrations.

It is valuable to elaborate, too, on how redundancy was fostered through the *Technology Together* process. As an approach to teacher professional development, *Technology Together* did not

seek to ensure all teachers developed the same knowledge or skill sets. Nor did it seek to establish consistent learning goals across a school, nor to impose any one form of learning strategy on the group. Rather, each teacher was encouraged to identify and celebrate existing skills and knowledge, to set their own goals (individual or collective) and to reflect upon the most appropriate strategies to assist them (with capability in mind). Difference and diversity within the whole school were celebrated and recognised as (at times) influencing the system in unexpected ways. For instance, the research documented how novice (unconfident) computer users could find themselves learning more effectively from each other than with the input of 'experts' (i.e. in a like-to-like mentoring context). The process also acknowledged that, for some teachers, a focus on recreational uses of technology (booking a holiday, shopping online etc) might provide a stronger motivational impetus for learning than a focus on professional applications, and that explicitly embracing and supporting this learning within the school might build confidence and reinforce strategies for other pedagogically focused learning.

Agent interaction is central in action research

Both complexity theory and action research are primarily concerned with the relationships and interactions between 'agents' (or participants). To draw from the work of seminal action researchers, Carr and Kemmis (1990, p.181):

...action researchers accept that transformations to social reality cannot be achieved without engaging the understandings of the social actors involved. They accept that understanding the way people construe their practices and their situations is a crucial element in transforming education...

Action research initiatives can, of course, differ in the degree to which they might be considered 'participatory' and they also can vary in terms of the first-, second- and third-person 'pathways' referred to by Reason and Bradbury (2008), who note that the most compelling and enduring action research engages in all three. As these authors elaborate, 'social and organizational realities may be understood to be outcomes of patterns of interaction between the members: in turn, the members' dispositions and practices are shaped by social and organizational procedures' (p.xxvi). Such a perspective is highly consistent with ideas underpinning complexity theories.

'Participatory' action research represents a form of decentralised control whereby the research is conducted, 'with, for and by' (Reason & Bradbury, 2008) people who 'share problems in common, decide what problems to tackle and directly get involved in research and social change activities' (Park, 2008). Such participatory processes open up what, in complexity terms, might be termed 'collective possibilities'. Davis and Sumara (2005b) describe complexity thinking as providing action research with a 'pragmatics of transformation' – as they elaborate, it provides 'advice on what one might do to help bring together the self-interests of autonomous agents into grander collective possibilities'.

As has been argued elsewhere (Phelps & Hase, 2002) the 'rules' or internal models of schemas that are spoken of in complexity theory can, amongst other manifestations, be interpreted in action research as 'assumptions'. Acknowledgment and challenging of assumptions is integral to action research and shared reflection and dialogue encourage participants to explore and challenge these schemas with other participants (agents). This process, in itself, might be considered as introducing 'noise' which actively promotes disequilibrium, a point we discussed earlier.

Agent interaction was certainly central in the *Technology Together* process where participating schools, teachers and, particularly, Companion Mentors played a major role in facilitating the research process. The nature and form of dynamic arising between participants was not ‘controlled’ as part of the research process. Rather, the nature of interactions, both planned and spontaneous, emerged from dynamics occurring within and between the schools themselves. Thus, while we prompted the schools to facilitate regular meetings and discussions, and to trial strategies for facilitating reflection, the nature of these gatherings and reflections was very much shaped by individual and collective ‘schemas’ and individual and cultural dynamics and histories of those participating. In some, whole-school staff meetings became dynamic places of learning and sharing. In others, learning was primarily occasioned more informally through chance interactions. For example, the location of staff computers in areas such as luncheon rooms or near photocopiers was documented as having a significant influence on both individual and collective learning outcomes.

Action researchers are interested in feedforward and feedback

Complexity theorists identify that complex phenomena embody their histories (Davis & Sumara, 2005b) and, in fact, that “historical events in all their idiosyncrasy are themselves the irreducible meat of what is going on” (Turner, 1997). Through processes of ‘feedforward’ and ‘feedback’, such ideas suggest that complex systems can respond very differently to identical circumstances since the system, not the conditions, determines the response. “Sensitivity to initial conditions” is a phrase often used by complexity theorists to acknowledge these ideas and to signal that processes are critically dependent on initial conditions, the complexities of which may be unrecoverable or unknowable.

Technology Together took as a starting point the understanding that any professional development activities within a school system needed to acknowledge these complex histories and the unpredictable influence of these histories on both individual and collective responses to change. The action research process began with an initial visit to each of the involved schools to document aspects of the school’s history, current context and culture, particularly in relation to ICT professional development and learning. This data was collected through interviews with key staff (such as Principal, Assistant Principal, ICT coordinators) as well as observations across the school and analysis of documentation. The purpose of these visits was not to attempt to reach a definitive understanding of the school’s background, nor to attempt to extrapolate on the likely influence of this background. Of course, it was acknowledged that no such process could lay claim to be anything more than superficial, since such initial conditions may (and probably are) unrecoverable or unknowable. Yet, as previously emphasised, this didn’t need to equate to unintelligibility but rather to the value of *different types* of understanding. In *Technology Together* we viewed this process as critical in raising awareness of the complexity of these many influential factors and we emphasised the capacity of participants themselves to continue to acknowledge and reflect upon past and present and its influence on ongoing action and change.

Action research embraces reflective processes

As has been argued elsewhere (Phelps, 2005), reflective processes, as a key component of action research, are a valuable means by which research can acknowledge, account for and document at least some of the complex interplay between ‘history’ and ‘initial conditions’ and change processes. Activities such as journaling or group reflection sessions can stimulate individuals and collectives to build up a holistic picture of the interplay of their past experiences and background with their current and emerging ‘state’, and in this way help them to understand the influence of ‘initial conditions’. No-

one knows the complex interplay of such factors or the significance of any one factor, more than the individual themselves. This is not to assume or claim that individuals or collectives are likely or able to be aware of all these factors, but more that they are in a better position than anyone else to do so.

Reflection was integral to *Technology Together*. The professional development approach embodied multiple reflection and dialogue opportunities and incorporated a range of stimuli which served to support the active and explicit fostering of reflection. An explicit emphasis was placed on discussing with teachers the value of capturing 'a-ha' experiences, which in complexity terms were often significant bifurcation occurrences for teachers in relation to their learning (Phelps, 2005). For example, a number of teachers came to the realisation that they didn't need to 'know' how to do something on their computer in order to have a go, and this was a major insight in prompting them to engage in more exploratory learning approaches. The significance of these events to the individuals or groups themselves could only really be known to them, and hence would otherwise have gone unidentified if participants themselves were not involved in reflecting on, and documenting, them. Creating a context where such events were acknowledged and valued was a critical part of the *Technology Together* and action research process.

Action researchers are interested in the 'exceptions'

While many research approaches have traditionally discounted outlying data, action research has tended to embrace and focus upon such data. Greenwood & Levin (2000) note that in action research any case that runs counter to a generalisation invalidates it and requires the reformulation of the generalisation (although we would re-emphasise our qualified understanding of generalisability in action research). Similarly, Dick (2000) advocates an approach to action research where if sources agree then the researcher searches for exceptions in the next cycle. If they disagree, then the researcher searches for explanations. While the language adopted by these authors in some respects runs counter to complexity theories, the notions being described are highly consistent. While positivist research has tended to disqualify exceptional cases, action research embraces them.

In parallel to these ideas, complexity theories identify that small consequences can evoke significant changes in outcomes. As previously outlined, it also places renewed focus on redundancy and diversity. We have already discussed the important role of history and background. All these elements emphasise the value of acknowledging and focusing on the 'exceptions', 'outliers' and contrary data in research. It is with such divergent or dissenting views, alternative approaches or chance happenings that emergent processes and even bifurcation points can be better understood. We would argue that it is the *dissonance* within systems, and the potential consequence of this dissonance, which holds the clues to understanding change processes – and action research assists us to document this. While any action research initiative requires some common and shared basis upon which stakeholders can engage in any shared process, action research also requires diversity to prompt emergence of new 'ideas' and hence more sophisticated possibilities for action.

Technology Together assumed such an approach. We were interested in those teachers who did not engage well with the metacognitive learning approach, as well as those who embraced it. We were interested in those strategies which schools trialled that had a major impact, as well as those which seemingly had little impact – and we were interested in exploring the richness of history, context and interactional processes which contributed to these dynamics.

Perhaps, and more controversially, our interest in outliers also assumed a particular form in our collection and analysis of pre-intervention and post-intervention data. We say ‘controversially’ because previously expressed ideas that complexity theory and action research might be well informed by mixed methods approaches (Phelps & Hase, 2002), have been critiqued by Davis and Sumara (2005b). We have not chosen to dwell on these arguments here, beyond signalling that there are aspects to this debate with which we agree. However what might be elaborated here is how we chose, in the *Technology Together* research, to employ a mixed method approach – in particular, how we integrated the collection and analysis of quantitative as well as qualitative data within the complexity framework of the research.

As previously stated, *Technology Together* used a diversity of data collection approaches, including a pre- and post-intervention survey consisting of a combination of Likert scale and open ended qualitative responses. As such, this may be consistent with more positivist, causally focused research. A key distinction, however, is in the ways in which this data was conceptualised and approached. The data was not intended to establish causal connections nor to make definitive claims about the ‘success’ or otherwise of the process (although it did enrich critical discussion around the process). Rather, this data was fed back to participants as a stimulus for reflection, discussion and planning processes. To return to the notion of being interested in ‘exceptions’, the survey enabled schools to develop richer understandings of their own situation at a particular point in time. It enabled them to identify diversity across their organisation, and they were able to reflect on their own schools’ context in the light of data from other schools. Through the reflective action research processes the ‘fuzziness’ inherent in the meanings and interpretations of the data were unpacked and problematised, and the value of the data in supporting the school (as a learning collective) became the focus. So, again, this mostly quantitative pre- and post-intervention data was not utilised in the conventional sense to simply measure and predict change, but rather to engage participants in dialogue and reflection around exceptions and outliers and what these might mean for them as a school.

Concluding comments

What might be said, then, about *Technology Together* was that as both an action research project *and* as a professional development approach it did (and does) not seek to achieve a simplistic or generalisable approach to ICT professional development. It isn’t a ‘quick fix’ nor can it be seen as an approach which is directly transferrable to different contexts. Rather, it is a process which views school communities as organic wholes. It acknowledges the complexity of factors influencing ICT learning for teachers and attempts to support them (and school communities as a whole) to embrace this complexity and to ‘go with the flow’. In this way, action research can support teachers, schools and educational systems to better understand aspects of complexity, including alternative perspectives on causality and emergent change processes. Therefore, rather than view models of action research from reductionist paradigms, we prefer to see action research as offering possibility and potential to actively and positively provoke change in understandings and practice. In other words, it can be a process that schools engage in to help them to understand and work with the complex dynamic of ICT learning.

We have already acknowledged that action research is not always consistent in every context with understandings from complexity theory, nor perhaps even with the deeper philosophical underpinnings of action research itself. This may well be the case within school systems such as those in the UK which Radford describes. However, to locate all action research within thinly disguised positivist discourses seems inappropriate. Rather than renounce the complementarity of action research and complexity theory, we would argue that the issue lies, instead, in the ontological, epistemological

and philosophical positioning of those conceiving of, driving, resourcing and conducting action research – and that an underlying understanding of complexity theories can enhance both. As Sumara and Davis (2009) indicate ‘neither action research nor complexity theory arrive “complete”’, but rather ‘both are understood as plastic and open to elaboration... both are oriented toward and by the complicity of the researcher’.

To conclude, we would like to acknowledge that although we have presented this paper as an illustrative response to the ideas expressed by Radcliff, we do so in the spirit of joining in the conversation and collective learning that is currently shaping a field which is (consistently) perceived as emergent. Complexity Science, we acknowledge, is ‘not simply a discourse to import, but one to be joined’ (Davis & Sumara, 2005a).

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