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Renata Phelps
Southern Cross University

Stewart Hase
Southern Cross University

Allan Ellis
Southern Cross University

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Competency, Capability, Complexity and Computers: Exploring a New Model for Conceptualising End-user Computer Education

Renata Phelps, Stewart Hase and Allan Ellis

Renata Phelps is a Lecturer in the School of Education at Southern Cross University. She teaches both pre-service and postgraduate teacher education students in educational information technology. Through her research she has developed and refined a metacognitive approach to computer education. Other research interests include complexity theories, action research and information and communication technology in schools. Stewart Hase is an Associate Professor in the Graduate College of Management, Southern Cross University where he directs the Doctor of Business Administration. As a psychotherapist he is interested in individual and organisational capability, and helping people change. Dr Allan Ellis is an Associate Professor in the School of Social Sciences at Southern Cross University. He teaches postgraduate courses in adult learning, instructional design, education technology and networked learning as well as supervising higher degree research students at Masters, PhD and DBA level. Address for correspondence: Dr Renata Phelps, School of Education, Southern Cross University, P.O. Box 157, Lismore, NSW Australia, 2480. Email: rphelps@scu.edu.au

Abstract
Notions of competency have dominated the computer education literature, and have underpinned Competency-Based Training (CBT) in information technology at all levels of education and training. The emergence of counter-narratives underpinned by the capability movement, have as yet had minimal impact on practice in computer education. New discourses in educational theory and practice which are founded on non-linear approaches to learning and teaching provide added impetus to engage in the competency/capability debate, and re-examine our approaches to computer education. This paper explores complexity theories and demonstrates how complexity's pedagogical implications can lead to new models for understanding computer learning and teaching. A new model for conceptualising end-user computer education is presented that was derived from a three-year action research initiative with pre-service teachers.

Introduction

While recent studies (for instance, Knezek & Christensen, 2000; Warner, 2000) document growing levels of computer competency among school students, there are still many mature-aged individuals, as well as many school leavers, who are insecure in their computer use. For this reason, end-user computer education and training in the use of computer software and hardware will continue to be a significant issue for business, industry, and educational contexts alike (Watson, 1997).

There is little research or documentation that discusses the teaching strategies employed in end-user computer education and training. Many computer training programs are directive in nature, guiding participants through a series of step-by-step instructions and focusing on one particular program or computer function. Certainly, educational contexts such as vocational education and training, which draw on competency-based approaches to learning, tend to be highly structured and directive, teacher-centred rather than learner focused (Hase and Kenyon, 2000) and, more often than not, have a 'poor rate of return' (Hase & Davis, 2002). These approaches might be contrasted to observations of the ways in which many individuals who become proficient at using computer technology learn, namely through self-directed exploration, as opposed to short courses or training sessions (Davis, 1999).

Computer technology is evolving at such a rapid rate that, if an individual undertakes traditional, directive-style training in how to use a particular piece of software, that knowledge is likely to be inadequate or out-of-date in a very short period of time: months not years. This rate of change places immense strain on everyone involved with computers, no matter what their skill levels. Computer

training thus presents significant challenges at the individual and organisational level because a relevant end-user computer education program requires more than skills training. It also involves changes in attitudes, values and beliefs that develop adaptability to change and confidence for ongoing learning. This paper proposes a model for computer learning that can be useful in informing new approaches to end-user computer education, approaches which can lead to computer capability and life-long approaches to computer learning.

The Competency/Capability Debate

The concept of 'capability' emerged from the UK in the mid 1980s as a response to the need for increasing organisational competitiveness and the rapid changes occurring in the nature of work (Hase & Davis, 1999). The capability movement was formalised with the publication of the 'Education for Capability Manifesto' (Royal Society for the Encouragement of Arts Manufactures and Commerce, 1996) and, around this same time, an Australian Capability Network was formed. A now strong body of literature supports the value of capability approaches to learning (Bawden, 2000; Cairns, 1996a; 1996b; 1997a; 1997b; Hase, 2000; Limerick & Cunningham, 1993; Price, 1996; Stephenson, 1996). Capability is perhaps most succinctly defined by Cairns (2000, p.1) as '…having justified confidence in your ability to take appropriate and effective action to formulate and solve problems in both familiar and unfamiliar and changing settings'. Capable people are those who know how to learn, are creative, have a high degree of self-efficacy, can apply competencies in novel as well as familiar situations and can work well with others (Hase & Kenyon, 2000). Capability draws on Schön's (1987) notion of 'professional artistry', and the importance of preparing students for 'indeterminate zones of practice': the 'unfamiliar and changing settings' referred to by Cairns.

It is impossible to discuss capability without comparing it to competency. Again, to quote Cairns (2000, p.2), competencies are 'individual and measurable skills demonstrated and assessed against agreed standards of competence'; whereas capability is 'an all-round human quality, an integration of knowledge, skills and personal qualities used effectively and appropriately in response to varied, familiar and unfamiliar circumstances'. Competency-based training (CBT) has its origins in the behaviourist movement which sought to focus attention on intended outcomes of learning and observable student behaviours (Bowden & Masters, 1993; Velde, 1999). This focus represented a shift from establishing an individual's 'knowledge' to an emphasis on ability to competently perform specific workplace tasks and roles and, as argued by Velde (1999) and Mulcahy (2000) the adoption of CBT has been driven by economic and social forces, rather than educational ones.

Adaptability to change and an emphasis on lifelong learning are thus central to capability but are usually conspicuously absent in competency-based initiatives. Competencies deal with the known, and the predictable, rather than unknown contexts. As Wildman (1996) states, 'competencies tend to be prescriptive and are designed for a more stable environment with familiar problems' (p.86). This is not to say that competencies are not important. As stated by Price (1996, p.4) 'they are a necessary aid to living and they give added confidence to individuals along the path of life'. While competencies may be an element of capability, it is the variable context and the notion of unpredictability which presents challenges: 'The problem with competency training is that it is always in danger of equipping the young for the performance of yesterday's jobs' (Price, 1996, p.4). Price draws another important distinction, stating that competencies are somewhat artificial in nature, representing a degree of simplicity rarely existing, whereas capability arises from the interaction of the individual with the world. It is notable that the vocational education and training sector in Australia has begun to look for something in addition to competency as a more 'holistic' approach to learning in the workplace (Hase and Davis, 2002).

Competency and Capability in Computer Education

The competency/capability debate is particularly evident in the context of computer education. Competency-based training was widely adopted throughout Australia in the 1990s, particularly in the TAFE sector (Australian National Training Authority, c.1998). More recently, 'VET in Schools' initiatives have brought competency-based training into the compulsory education context (Griffin & Gillis, 1998; NSW Ministerial Advisory Council on the Quality of Teaching, 1997; Spring, 1999). In 2004 NSW will introduce competency-based assessment for all year 6 and year 10 students (NSW Board of Studies, 2002). Further evidence of the strong impact of CBT on computer education and training is evident in the 'International Computer Drivers License' (European Computer Driving License Foundation, 2002) and similar such training packages.

While CBT approaches are continuing to have a strong impact on computer education and training at all levels in Australia, some evidence *is* beginning to emerge of the transition toward capability-based, rather than competency-based approaches. For instance, in 1998 the Victorian Department of Education, Employment and Training released a document *Learning Technologies: Teacher Capabilities Guide* (2000). While no rationale is provided for their choice of term, a notable 'capability' promoted in the document is that teachers should 'continually develop skills, knowledge and understandings of learning technologies': in other words, capacity to embrace lifelong learning. Similar attempts to widen the notion of competency are made by the New South Wales Department of Education and Training by their inclusion of a competency in each syllabus document which reads: 'Develop the confidence to explore, adapt and shape technological understandings and skills in response to challenges now and in the future' (NSW Board of Studies, 2001). While this outcome is laudable in principle, and highly consistent with capability, the ability to develop or assess such personal attributes in a competency-based framework is highly problematic.

The Australian Council for Computers in Education (ACCE) has also bought into the competency debate in a linguistic, but perhaps not conceptual, sense. In their preamble to *Teacher Learning Technologies Competencies Project Background Paper* (ACCE, 1999), they state that 'for some people the notion of competence deflects from a holistic view to one diminished to a list of skills and for others it represents a strategy for defining professional standards' (p.2). They go on to state that the term 'capabilities' has been adopted by some to 'help educational communities understand the competency movement in Australia as a professional development strategy and not a testing mechanism' (p.2). Their distinction goes only a small part of the way in distinguishing a 'capable' computer user from a 'competent' one. In fact, the way many of these organisations define capabilities is *as* competencies: discrete, definable attributes, rather than the holistic conception of capability defined in the previous section.

The 'capable' computer user might be paralleled with the exploration of self-taught computer-using teachers provided by Chandler (2000). Chandler speaks of teachers who have learnt to use computers out of their own enthusiasm, without substantial training. They feel comfortable about learning any software, are willing to 'have a go' and are generally not intimidated by computers. A capable computer user has an ability to adapt to change, employs self-directed learning strategies, has a willingness to experiment, recognises appropriate avenues for integration, and is prepared to persevere. As we shall demonstrate, capability and its development, are underpinned by a relatively new perspective offered by complexity theories.

The Research Context

The theoretical exploration provided through this paper grew from an action research undertaking conducted over four years and aimed at developing teaching approaches which foster computer capability. The research focused upon the development and delivery of a tertiary computer unit (a 150 hour course) offered as a core to pre-service teacher education students in both the Bachelor of Education (Primary) and Diploma of Education (Secondary) degrees at Southern Cross University, NSW, Australia. The Unit is multi-mode delivered, taking the form of a Web-based resource (also available on CD-ROM) supplemented with optional face-to-face tutorials. The content deals with a range of topics including the Web, e-mail, mailing lists, synchronous communications, spreadsheets and Web publishing, together with the application of IT in learning and teaching including pedagogical, social, ethical and legal issues. In developing this Unit a particular focus was placed on developing 'capable', rather than 'competent' computer users.

Action research was deemed to be an appropriate methodology to pursue both change (action) and understanding (research) (Dick, 2000; Carr & Kemmis, 1990). Action research is participatory research, 'directed towards and directed by those who are actually taking the journey' (Grundy, 1995, p.9). As such it provided an opportunity to elicit a greater understanding of computer capability while also developing practical change in teaching methods. As argued elsewhere (Phelps & Hase, 2002) action research is also an appropriate methodology for pursuing complexity-based research.

The research consisted of three distinct cycles over the period of 1999-2001, each consisting of phases of planning, acting, observing and reflecting and each progressing understanding of the learning experiences of successive groups of students. Data were collected in each cycle using multi-method approaches including survey instruments, observations and qualitative data drawn from reflective journals maintained by teachers and students over each teaching period.

Before exploring complexity theories in further detail it is appropriate to briefly outline some of the other relevant findings of the research which have been reported elsewhere. The research led to the development of a metacognitive approach to computer education (Phelps, 2001; Phelps & Ellis, 2002a, 2002b; Phelps, Ellis & Hase, 2001), defined as that which assists students to become more aware of their attitudes towards computers (metacognitive knowledge) and their past and current learning approaches with regard to computer skills (metacognitive experience and strategies). As part of this process, students over the three cycles explored the concept of computer capability, reflecting on the learning approaches adopted by proficient computer users. As reported elsewhere (Phelps, Ellis & Hase, 2001) they identified a core set of characteristics of computer capability which included: confidence in their own skills and abilities; patience and persistence, determination and calmness; risk taking, courage to experiment and try new things; not afraid to make mistakes; methodical/logical thinking; enthusiasm and motivation; enjoyment of computers; positive attitudes and interest; technical knowledge; love of learning; constant use and deep immersion; and problem-solving abilities/deduction. Notably, the majority of these are metacognitive constructs, and support the idea that computer capability is less about technical knowledge and more about having a sound ability to learn.

The latter phases of this action research undertaking were informed by complexity theories and it is this theoretical foundation that is the focus of this paper. What follows is a brief exploration of complexity theories, followed by the presentation of a model for understanding competency and capability, as it relates to the computer learning and teaching context. This model will be discussed with reference to the findings and experiences of this action research study.

Complexity and its Application in Education

The literature explicating complexity is comparatively recent, owing much of its development to a group of eminent cross-disciplinary researchers, several of them Nobel laureates, working at the Santa Fe Institute in the USA. Complexity theory is essentially a formal attempt to question how coherent and purposive wholes emerge from the interactions of simple and sometimes non-purposive components (Lissack, 1999). At its most humble, it attempts to explain the 'big consequences of little things'. Seminal works in the area (for example, Capra, 1982; Kauffman, 1995; Pagels, 1988; Progogine & Stengers, 1984) have laid the groundwork for research in a broad range of disciplines from evolution, immunology, architecture and economics to psychology and education.

Complexity is concerned with open, non-linear systems. An open system is one that needs and receives energy to maintain its order and where this maintenance of order places the system in a state that is far from equilibrium. A non-linear system is unpredictable in that, even if one was familiar with all the components of the system, one would still not be able to determine exactly what would happen next. Such a system is thus greater than the sum of its parts. Complexity acknowledges the inability to totally understand the whole through an understanding of the parts but rather aims to understand the whole by understanding the *interaction* of its parts. Complexity theory is founded upon alternative conceptions of causality, acknowledging that uncertainty of prediction is inevitable (Eve, Horsfall & Lee, 1997) and that processes are critically dependent on their initial conditions, conditions that may be unrecoverable or unknowable. This is the essential notion behind the well known 'butterfly effect', a term arising from the meteorological modelling of Lorenz (Waldrop, 1992). Sensitivity to initial conditions means that the long term trajectory of a system is highly sensitive to its starting point and that long term behaviour of a system is determined as much by small chance changes as by deterministic laws (Stacey, Griffin & Shaw, 2000).

Complexity proposes that interacting agents transcend themselves by acquiring collective properties they would not develop individually (Bossomaier & Green, 1998; Kauffman, 1995; Stacey, Griffin & Shaw, 2000). The term *autopoiesis* is used to refer to the patterns of self-generating, self-amplifying and self-maintaining systems. Systems can be structurally stable or unstable. A structurally stable system is unaffected by minor changes while a structurally unstable system is one in which a minor change results in a major change in the whole system. *Bifurcation*, or phase transition, is the term used by complexity theorists to describe the branching of phenomena seen during chaotic episodes (Price, 1997). Bifurcation usually results in new but more complex stability. There is unpredictability at each bifurcation point since no subsequent state is deducible from the previous one (Stacey, Griffin & Shaw, 2000). From a complexity perspective, development and change is viewed as a natural and evolutionary process which is neither imposed nor random (Doll, 1997-8).

To summarise, complexity emphasises the importance of acknowledging the whole range of variables impacting on any context and the inability to control such variables while maintaining contextual integrity. Complexity represents a recognition that the world is irreducibly complex, not determinist and predictable, and that the task before us is no longer to identify the simple elements of reality underlying complex appearances, but to work out how to study complexity in its own right (Gare, 2000).

When applied to the context of education, complexity provides a perspective on learning based on non-linearity of thought and on variation as a source *and* outcome of thinking (Bloom, 1998; 2000) or as Doolittle (2000) describes it, learning as self-organised adaptation. Complexity views student thinking and learning as an emergent process where ideas and concepts arise from specific contexts.

The emergence of such ideas are inherently non-linear and unpredictable: 'Although we may be able to predict that certain types of events or ideas may arise, we cannot predict the specific content or outcome' (Bloom, 2001a, p.23). Agents play an active role in co-constructing knowledge through interaction with others and with their environment (Jorg, 2000) and an importance is placed on the influence of variance, encountered through this interaction, as both source and product of cognition. As Stacey, Griffin and Shaw (2000, p.x) emphasise, learning is a process of 'co-evolution of jointly constructed reality'.

Davis and Sumara and other co-writers (Davis and Sumara 1997a; 1997b; Davis, Sumara and Kieren 1996; Davis, Sumara and Luce-Kapler 2000) apply complexity thinking in their proposal of an 'enactivist' model of cognition and make recommendations from this for teacher education. Enactivism is defined as a form of collective cognition (Sumara & Davis, 1997a), an idea which challenges understandings of individuals as the locus of cognitive development. Rather, cognition is understood 'as a process of organizing and reorganizing one's own subjective world of experience, involving the simultaneous revision, reorganization and reinterpretation of past, present and projected actions and conceptions' (p.107). This model challenges cognitivist tenets that superior ideas supersede inferior ones and that we are on a linear path of progression toward better and more accurate understandings, either individually or collectively. These ideas are best presented through a direct quotation from these theorists:

...the tendency to regard learners as situated within particular contexts is rendered problematic. Rather, the cognising agent is recast as part of their context. As the learner learns the context changes, simply because one of its components changes. Conversely, as the context changes, so does the very identity of the learner... how we define ourselves and how we act is inevitably affected. And so, learning (and similarly teaching) cannot be understood monologically: there is no direct causal, linear, fixable relationship among the various components of any community of practice. Rather, all the contributing factors in any teaching/learning situation are intricately, ecologically and complexly related. Both the cognising agent and everything that it is connected to are in constant flux, each adapting to the other in the same way that the environment evolves simultaneously with the species that inhabit it (Sumara & Davis, 1997a, p.414).

Current educational practices are teacher centred and modernist. They construe teaching as a more simplistic cause-effect system that is outcome rather than process based. Nothing could be further from the truth. Both students and teachers bring to the learning environment a wide mix of variables, and the unpredictability of these variables is the rule rather than the exception. Foundational to complex thinking about education is the notion that teaching does not necessarily *cause* learning and learning cannot be pre-determined or 'caused' (in linear terms) by teaching:

...all of our understandings are situated in and co-emerge with complex webs of experience, and so we can never discern the direct causes of any particular action. Trying to establish a causal relationship between one event and another, or between a teaching action and a learning outcome confuses essential participation with monologic authority (Sumara & Davis, 1997a, p.412).

From this perspective, learning is occasioned, not caused. While we can present occasions that are rich with learning possibilities and in which we might participate with our students in the unfolding of understandings, we can not prescribe what will be learnt. 'Teaching and learning must be understood as simultaneously shaped and being shaped by the circumstances in which they occur' (Davis & Sumara, 1997a, p.116). Complexity's perspective on teaching and education thus represents an acceptance of uncertainty as part of the nature of education. Such perspectives on teaching echo the metacognitive approach to computer education (Phelps & Ellis, 2002a, 2002b; Phelps, Ellis & Hase, 2001) which was developed through this research as this approach does not attempt to 'force' change in student behaviour, but rather to provide rich stimulus for their own learning to evolve.

Complexity-based educationalists (for example, Doll, 1989a; 1989b; Doll and Alcazar, 1998; Iannone, 1995; Sawada & Caley, 1985) see the contemporary focus on objectives and learning outcomes as representative of an obsession with domination, control and reductionism. When teachers and educational systems attempt to pre-define and pre-structure curriculum they are working against the very notions of emergence. Pre-set outcomes must be 'set aside in favor of more holistic, all-at-once co-emergent curricula that are as much defined by circumstances, serendipity, and happenstance as they are by predetermined learning objectives' (Davis & Sumara, 1997a). Teachers need to accept students' ability to organise, construct and structure learning, combining supportive and challenging behaviour; equilibrium with disequilibrium. 'Curriculum becomes a process of development rather than a body of knowledge to be covered or learned, ends become beacons guiding this process, and the course itself transforms the indeterminate into the determinate' (Doll, 1989a, p.250). Doll also adds that lessons should not focus on closure but rather on providing just enough disequilibrium to combine closure with openness. It is these approaches which underpin the proposed model of end-user computer education which is presented in the following section.

Fresh Perspectives on Competency and Capability

Complexity theories provided stimulus for greater understanding of not only computer learning and teaching, but of the notions of competency and capability themselves, as they relate to end-user education. In this section we present a new perspective which is informed not only by these theoretical ideas, but the findings and developments from the action research study. This alternative perspective will be discussed through reference to the diagram presented in Figure 1.

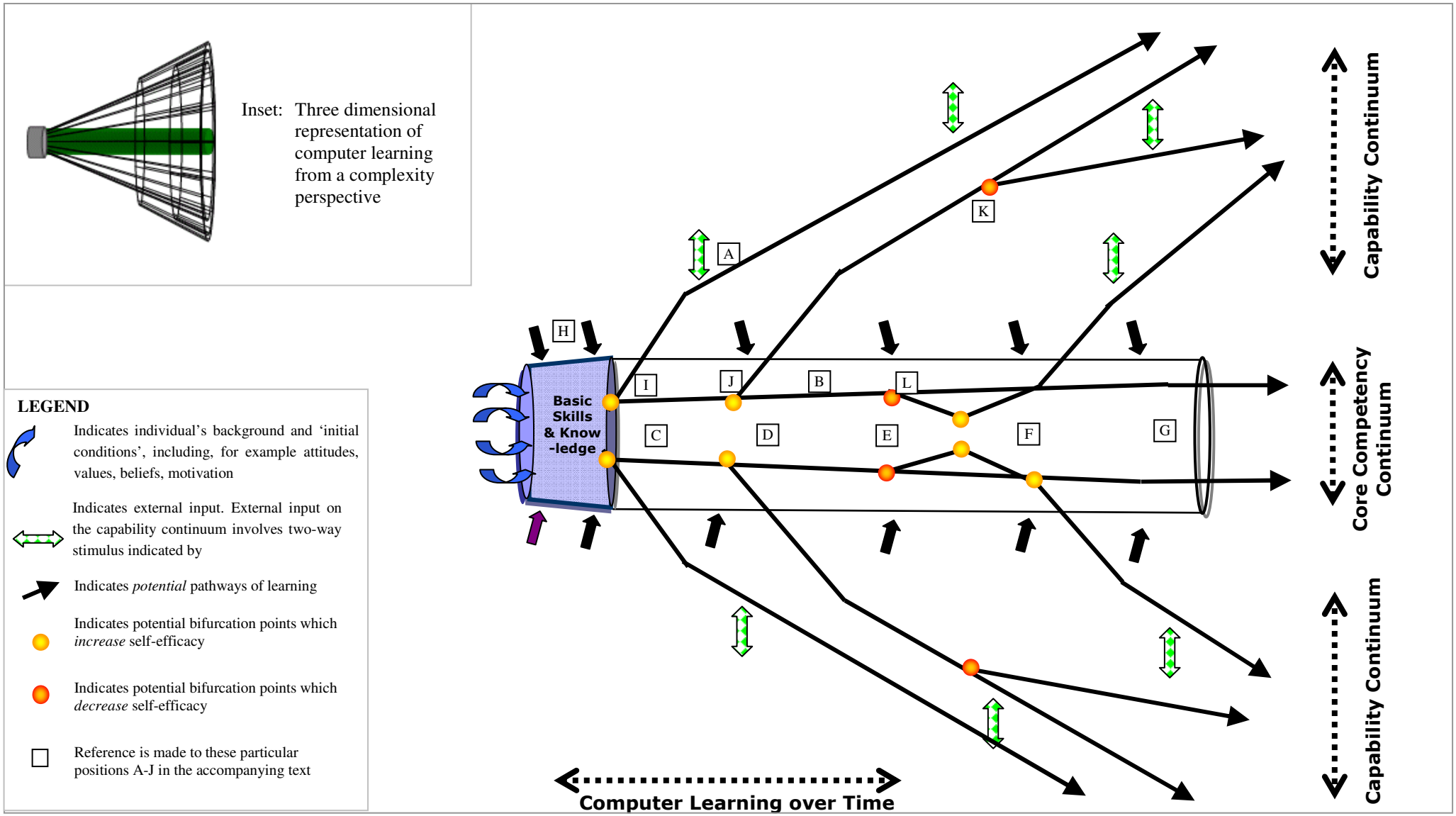

Figure 1: **An interpretation of computer learning from a complexity perspective**

Figure 1 is a two-dimensional view of a three-dimensional model (as per the insert). In summary, the diagram illustrates potential paths of computer learning over time, acknowledging the variable development of both competency and capability. The figure indicates a common foundation in basic skills and knowledge but demonstrates how external input or stimulus can create bifurcation points. Bifurcations can either decrease computer confidence or increase computer confidence and skills, thus forming a transition from a continuum of 'decreasing returns' to one of 'increasing returns' (or vice versa). Figure 1 depicts the limitations of competency and the potential of capability. What follows, then, is an elaboration of these points and a more detailed exploration of the model with reference to the specific research project and context outlined earlier.

The first point to make about the figure is that computer learning occurs over time. Although figure 1 shows learning as continually moving forward, it could stagnate or slow at any stage. Hence the horizontal axis of time is not quantitatively accurate or to scale, but rather a fluid notion of *potential* individual development over time. Figure 1 indicates that capability-based learning may take more time, however the outcomes are *potentially* 'exponentially' greater.

Secondly, both competency and capability are viewed as continuums, along the vertical axis, with competency representing a more defined and limited concept than capability. There is no notion of 'being' competent or 'being' capable, in a final sense. Rather, the concepts might be considered as matters of 'becoming' (Sawada & Caley, 1985). While it is possible to identify individuals who might be described as 'capable' or 'competent' (as occurred in our own research) such comments are not meant to imply that these individuals are in a 'final' or stagnant state of development, but rather, that they are moving along the path of growth. There is no end-point to the two concepts or final, ideal state. In fact, capability requires a recognition of this very notion in order that the individual embraces lifelong learning (see also table 1).

The third point to make in relation to the figure is that competency and capability share a common foundation in basic skills and knowledge. As was explored with two small groups in our research there are some core skills and understandings which ground both competency and capability. It might be asked, then, whether competence is an essential ingredient of being capable. As argued above, competency and capability are both transformative continuums. Given that neither has an 'end state', *per se*, then neither can precede the other. An individual at position A (in the figure) on the capability continuum may have less skills and hence competence than an individual at position B, yet the individual at position A has greater capacity to respond and adapt to change, and therefore, in the 'bigger picture', may be better off.

Fourthly, figure 1 indicates that the path toward competency implies more narrowly defined outcomes and less capacity to adapt to an unpredictable context than the path toward capability. The diagram depicts the broadening and unpredictable base of skills, knowledge and abilities emerging from capability-based approaches. In a competency-based approach the outcomes at any one stage (for example, positions C-G) can be defined and predicted. This is because there is stability and control in the learning/teaching dynamic. As mentioned earlier, the learning may, however, stagnate at any one of these points (for instance, when training finishes) as the system relies on external input. Individuals on the capability path, however, may have undefinable or unpredictable skills, knowledge or abilities and there is far less control over the learning process. Capability is not a closed system but an open one.

The fifth point to make is that external input or stimulus of some form is usually required in the initial stages of computer learning, as indicated at position H. However, competency-based teaching approaches represent what in economic terms is referred to as decreasing returns, or in complexity as *negative feedback*. As

explained by Marion (1999) and Waldrop (1992), negative feedback suggests that maturing systems eventually run out of steam, reaching a point in development at which further effort provides negligible returns and they settle into an equilibrium state (for example, position G). Homeostasis, according to systems theory, derives from the dampening of variation by negative feedback. The path toward competence, then, continues to require external stimulus as it progresses (as indicated by the bold, black arrows). Again, this stimulus might take many forms, most likely training or other direct instruction. Practice, of course, reinforces skill development and increases computer confidence; however, this alone does not lead to significant improvement or widening of ability. In our own research, the case study of one student might be cited as an example of this. Despite strong confidence and experience he had not explored and discovered easier means of double spacing his essays than using two carriage returns at the end of each line. Despite high confidence his learning seemed to have stagnated. External input (for instance, tutor feedback) was needed to evoke change. Capability-based teaching approaches, on the other hand, represent increasing returns, or in complexity terms, *positive feedback*: the deceptively simple idea epitomised by a rolling snowball, gathering speed and momentum. The capability pathway also involves input, but the difference here is that the stimulus is more likely to be two-way (as indicated by the green, dotted arrows). Capable individuals are more pro-active in their adaptation, actively seeking interaction with agents to address their learning needs, whether it be individual assistance, group instruction, interaction with resources, or implementation of self-directed strategies, including help-seeking strategies. This more intense embracing of agent interaction and pursuit of constant change and development might be considered as depicting individuals 'at the edge of chaos'.

Sixthly, the diagram attempts to represent the influence of background and 'initial conditions' (as indicated by the blue, curved arrows). These factors might include encouragement by others, use by others, perceived usefulness, support, attitudes, values, beliefs, motivation and attitude to learning in general. These 'initial conditions' influence the resultant dynamic in unpredictable ways. For instance, increased use by others does not *cause* higher computer self-efficacy or confidence, nor does increased support. Many students in the study perceived that computers had high usefulness but had not progressed far along the continuum of either competence or capability. Similarly, while for some students high levels of support enhanced their computer self-efficacy, for others it led to over-dependence and lack of confidence. Hence, initial conditions produce a complex and unpredictable context for computer learning and teaching. Only the individuals themselves can begin to grasp the personal influence of these factors; hence the value of involving learners in metacognitive engagement (Phelps & Ellis, 2002a, 2002b, 2002c; Phelps, Ellis & Hase, 2001).

In the seventh instance, the diagram conveys that the transition from 'competence' to 'capability' can occur anywhere along the developmental continuum. Drawing on the language of complexity this can occur at *bifurcation* points (for example, positions I or J)**.** In this sense, bifurcations are events or reflective realisations that do not correspond with previously held concepts, theories or beliefs (Bloom, 2001b) and thus challenge and evoke significant change: what are sometimes referred to as 'ah-ha' experiences. The foundational idea of 'big outcomes of small things' might be emphasised here. This research would seem to support complexity's premise that bifurcation points cannot be 'caused' or predicted. Rather, such changes occur through 'systems instability'. In the computer context instability is endemic, yet individuals can either ignore or embrace this instability. Recognising and embracing the context of continuing change can be one potential stimulus for bifurcation from competency to capability. Other potential stimuli drawn from the research data are outlined in table 1.

Table 1: Potential stimulus for bifurcation from competency-based to capability-based learning

POTENTIAL STIMULUS FOR BIFURCATION
Embracing the context of continuing change and/or recognising that learning must be lifelong
Realising the importance or benefits of using technology, including perceiving usefulness for either professional and/or recreational purposes
Realisation that current skill levels are inadequate This can lead either to increased competence (the individual learns a particular skill) *or* increased capability (the individual realises they need to set more continuous and ambitious goals)
Realisation of learning stagnation
Increased opportunity to 'play'; can involve purchasing a computer or actively pursuing increased access
Realisation of ability to learn independently or use help. Often occuring through trialing and succeeding via independent or exploratory learning approaches
Self-realisation and affirmation of current abilities
Recognition that some problems are beyond our control (appropriate attribution) or that problems are 'normal'
Realising the influence of affective dimensions (for instance anxiety) on learning
Realising that you don't need to know everything to be 'capable'
Successfully working through a problem

A question which again arises is whether or not bifurcation is always sudden. Drawing from experience in the research, while this was not *always* the case, it was not uncommon for students to express a sudden 'ah-ha' experience in their journal; 'The notion of perceived usefulness hit me like a flash of light'. Figure 1 also illustrates that bifurcation does not always lead to an increase in either competency or capability and can prompt temporary, and perhaps even permanent, decreases in computer self-efficacy (as illustrated at position K or L). One student in the research reported having high computer self-efficacy 3½ years before coming to university as she had used computers widely in her workplace. Leaving that environment had decreased her confidence dramatically as she no longer pursued ambitious learning goals. While our research has supported claims that bifurcation cannot be 'caused', it is possible to see that an environment of instability *can* be promoted, and this, it can be argued, is the primary role of the 'teacher'. Capability represents a new level of 'order' and reassurance which lies with enhanced computer self-efficacy and the belief in one's ability to meet new challenges.

In summary, then, figure 1 represents what this research has supported as being the differences between computer competence and computer capability, and the influences on learning within this framework. Notably this representation has not moved closer to a strict definition of computer capability, or a formulaic approach to its identification or development. To do so would be inconsistent with the espoused view of capability as a continuum and complexity's conceptions of emergence. Rather, this view is reflective of Cairns' (1996b) statement that, while capability is an elusive and 'tricky' notion to explain, this, paradoxically, is a strength, in that it does not allow a narrow or prescriptive perspective to be taken

Implications for Practice

While this paper has focused primarily on presenting and exploring theoretical ideas concerning competency and capability within the computer education context, and the enhanced understandings which complexity theories can provide, brief mention will be made in this section of the influence this theory had on the teaching processes and practices within the unit of focus in this research.

As a result of the insights and understandings gained through the study, the unit resources were redeveloped with far more flexibility in the learning 'pathways' presented for students. As reported elsewhere (Phelps, 2003), non-linear learning was embraced in both the design of the unit Website, and in the learning processes and structures. Students were no longer required to engage in the content in the same way, in the same

timeframe or order and they were given flexibility to respond to their specific learning needs. The unit resources became increasingly complex and multi-layered, but with scaffolding in the form of prompt questions and a rich variety of resources and activities of varying levels of difficulty. These learning prompts were utilised to challenge students from their level of 'comfort' with technology and encourage them to take on new and ambitious learning goals. Consistent with the metacognitive approach, the emphasis was on students identifying their own learning needs, and reflecting on the strategies most appropriate to achieve these goals, including appropriate help-seeking and support structures. Reflective journals were used as assessment tools to enable students' to present their personal path of development in divergent ways. This approach also had an 'equalising' effect, with all students, regardless of their prior level of experience or competence, being required to demonstrate progress on their identified goals… and hence their ability to respond to new learning challenges. The journaling process also enabled students to capture 'ah-ha' experiences, and hence gain insight into the significant impacts on their learning. Hence, rather than a set of defined competencies being the focus of the teaching and learning process, the explicit goal was instead on fostering capability.

The research provided significant insights into the role of computer teachers, particularly the importance of explicitly acknowledging the breadth of authentic support structures which are important for lifelong and non-institutionally-based learning and fostering students' help-seeking strategies. The research provided personal insights into ways to best work with students who are not ready or willing to engage in self-directed, reflective or flexible learning, and ways of assisting students to be more comfortable existing 'at the edge of chaos', an inevitable location in a rapidly changing technological environment. The research also revealed the richness and breadth of issues impacting on computer learning and emphasises that, to obtain a workable and effective understanding of computer learning, it is necessary to consider factors such as learner anxiety, motivation, self-efficacy, outcome expectations, learning strategies and help-seeking; but, more than that, it is important to keep in mind complexity's postulate that the whole is 'greater than the sum of its parts'. From such a perspective it is not enough to understand the computer learning context by understanding the influence of these individual 'parts' or factors. Rather, we need to work toward understanding computer learning and teaching by understanding the interaction of these 'parts'. Only the learners themselves are positioned to reach such complex understandings and to support their own learning and, for this reason, it is important to conceptualise computer education in a metacognitive framework. In a context of rapid technological change, computer education must be about 'learning to learn'. The resultant changes to students' learning perhaps most significantly lie in their awareness of the criticality of lifelong learning in the area of ICT. As future teachers, such insights are essential.

Conclusion

The ideas presented in this paper are thus equally derived from theory and practice. Likewise, they challenge transformations in both theory and practice within the area of end-user computer education. The argument for adopting capability-based approaches to computer education are well justifiable in the context of rapid technological change. It is not possible for us as educators to identify what end-user computer learners will need to know in the future. What we must instead focus on is equipping them to adjust to uncertain, changing and very complex futures. Yet it remains true that it is 'simpler' to teach from a competency-based approach than a complexity-based one.

We would seem to be standing at a cross-roads – a point at which our education systems could 'bifurcate' to a system supportive of lifelong learning, or one which continues to institutionalise learning. Training sectors are still perpetuating dependency, rather than fostering self-direction. We continue to condition learners to be passive recipients of transmitted information, values that work against the need of modern workplaces for self-directed learners and capable computer users. Without the inclusion of units such as the one developed

through this research, it seems unlikely that the situation in our education systems will change. If we are to assist our students to embrace lifelong learning, it is of critical importance that future teachers are exposed to a range of educational contexts, including those embracing non-linear and emergent understandings of learning. As Davis and Sumara (1997a) argue, reproducing teaching practices that are founded on limited conceptions of learning and cognition reproduce rather than transform school settings in which students and teachers feel disconnected from past, present and projected worlds of experience. This research has indicated that opening up such opportunities for teachers holds the potential for creating longer-term change.

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