Past into present into future: information and communications technology tools for the 21st century

Editorial – D. Dicheva, B. Du Boulay, P. Kommers, L. La Velle and J. Nichol

This Special Issue of the *International Journal of Continuing Engineering Education and Lifelong Learning* brings together research findings and theoretical perspectives at the interface between the learning society of the 21st century and cutting edge developments in cognitive and computer science, developmental psychology and education. The catholic nature of the findings is reflected in the cosmopolitan list of authors from 17 countries and five continents, who delivered papers at the *International PEG99 Conference* 'Intelligent Computer and Communications Technology – Teaching and Learning for the Twenty First Century', from which the papers in this issue were selected. This conference was held at Exeter, UK in July 1999 and was the latest in a series running from 1985 under the auspices of PEG. The PEG conferences have always been multidisciplinary, interested in the advances in educational technologies with a special focus on the application of artificial intelligence methods and techniques and the most recent information and communications technology (ICT) developments. They have always featured a mix of academics and practitioners.

A common feature of the conference papers, reflected in this Special Issue, is the specification and prototyping of computer-based tools and systems that reflect the demands of contrasting learning situations and environments. These cultural constraints relate to a range of educational experiences mediated through distributed networks for distance learning in home, school, college, work, and leisure environments. The unitary thread that connects the papers is that of knowledge management within discrete situated cultural milieux.

Because of the extent, complexity, and sheer overwhelming, exponentially expanding volume of data in the modern world, computer-based tools are vital for information handling and knowledge management. At the heart of the modern information society is the organizing, accessing, processing, analysing and restructuring of data in relation to our individual and collective goals. It is in this way that we use intelligently the new communications and information technologies, dependent as it is upon the research community represented at conferences like *PEG99*.

Cognitive tools sit at the confluence of four main streams that flow through the papers in this Special Issue: key skills, cognition, simulation and distance learning. Key skills are essential for using cognitive tools, reflected as they are in the particular skills and processes that each tool requires. Such skills are metacognitive, i.e. not specifically related to a particular disciplinary field or technical ability. In their paper 'Developing basic key skills through the use of ICT tools', Rosa Maria Bottino and Paola Cutugno seek to establish a link between some key skills and how computer-based tools foster and develop such skills in the educational contexts of schools. The metacognitive skills are transferable both between particular school settings and, inferentially, the expectations of

employers. Prophetically, Bottino and Cutugno reflect upon the interface between key information handling skills and school learning environments with their specific focus upon content and pedagogical issues.

Cognitive processes that underpin the acquisition of key skills are also truly relevant to the design of cognitive tools like Inter*Modeller, analysed in this issue. Tom Conlon's paper 'Inter*Modeller: multiple, interchangeable representations for classification model-building', describes a cognitive tool for building models of subjects that can be modelled in three overlapping ways: the scaffolding of information using grids, tables, flow charts, and classification trees; the organizing of data in classification; and syntactic conceptual clusters. Syntactic understanding involves skills in selecting, constructing, and interpreting commonly occurring representational forms: Conlon's 'representational competence'. Used by learners from about the age of eight, Inter*Modeller targets pupil learning of domain knowledge, classification skills, and representational competence. These principles inform the tool's design. Conlon's initial results suggest that the design methodology is sound, including support for multiple representational forms, automatic transformation between forms, and the ability automatically to convert an inefficient model into an efficient one.

Alexandra Cristea and Toshio Okamoto adopt a complementary approach to designing a cognitive tool to support teaching and learning in fields where practical cases come in the form of raw data time-series (usually presented as lists or charts), as for example, in stock exchange or weather forecasting. Their new technology is based on the premise that the knowledge has been previously learned by an artificial neural network (ANN) and stored sub-symbolically) in a form of weights and biases of that ANN. since the knowledge embedded in an ANN is hidden in its neurons, it is difficult to be understood and used for classroom teaching. Cristea's and Okamoto's 'Knowledge Extractor' allows access to the hidden knowledge embedded in an ANN by transforming it into a set of rules, understandable to the human users.

The importance of situated cognition reinforces the emphasis that theories of cognitive apprenticeship place upon the particular complex circumstances within which learning occurs and which shapes the interactivity of teachers and students. The situational change in emphasis from the late 1980s is reflected in the role of learning companions in intelligent tutoring systems. One such learning companion described by Jorge Ramírez Uresti in his paper 'The LECOBA learning companion system: expertise motivation and teaching' sees the computer-based companion work beside the human tutor and the student. Uresti explores the hypothesis that a less capable learning companion would be helpful to students in their learning by encouraging them to teach it. This innovative twist to the learning technology exploits the old principle of learning through having to master a subject, and then representing a model of the knowledge in a form that a learner can access and assimilate. Uresti addresses related vital issues, such as the motivation of the student to interact with the companion and the learning companion's knowledge of the domain.

What kind of cognitive learning tools can the architectures that underpin the perspectives of Bottino and Cutugno, Conlon, and Uresti produce at the classroom chalk-face? A simulation produces a model that reflects the framework of a particular learning situation. The computer can represent that model through its ability to store, access, and manipulate data and images. It can activate the framework's variables according to sets of parameters, encoded rules and inputs of data. Pupil interaction with a computer simulation enables the model's features and functioning to be assimilated; the dynamic

element motivates learning through actively involving the student as a participant in real world, even life and death decisions. The simulation differs from actuality in one, vital respect. The simulation enables the exploration of a full range of possible outcomes of situations and their consequences, thus both widening and deepening perception. For the pupil becomes an agent in the microworld that the model represents: in turn the model becomes an extension of the pupil's mind. The resolution stage of a simulation, in which the pupil represents the knowledge that he or she has constructed to an audience, involves the formalization and consolidation of understanding.

Two papers in this issue illustrate in contrasting ways the power of simulation to intrigue, motivate, engage, and deepen understanding. Peta Wyeth and Helen Purchase in 'Exploring the learning potential of an artificial life simulation' use a computer simulation to allow primary school pupils to explore the important scientific concepts of energy and change, life and living, and feedback and continuity through creating their own microworld. Artificial creatures with definite features, attributes and behaviours people the microworld. The pupils bring the environment to life through their choice and specification of parameters that determine and control the lives of the creatures. Wyeth's and Purchase's simulation system CULTURE employs the metacognitive skills that Bottino and Cutugno stress, developing problem solving, critical thinking and skills of analysis, extrapolation, inference, and judgement. The concept of mental engagement is central to CULTURE; as such it reflects the concerns of Conlon.

The explosion of possibilities for acquiring information has opened the reality of distance learning through computerized communication and support systems. The synchrinosity and virtuality that this implies means that the spatial and temporal constraints on constructing communities of learners have disappeared. In their paper 'Networked tools in interactive learning: an approach to the future', Jari and Teija Multisilta give us a glimpse of a possible future reflecting their experiences gleaned from several network-based distance learning courses that include applications of mathematics, computer science, and foreign languages. Central to their developmental program is an interactive learning environment in which students, teachers, experts and authors of learning materials can interact. The Mulitisiltas suggest that collaboration tools, where students work together on problems, effectively engage distributed learners on joint tasks through the ICT medium. This new learning paradigm reflects cognitive learning theories grounded in Vygotskian insights into the nature and role of social learning. The system of networked tools supports the learners, working cooperatively in a team. When the system is no longer able autonomously to provide useful advice, learners are supported by the teacher through the network.

Similarly, Cecília Baranauskas, Nelson Neto and Marcos Borges in 'Learning at work through a multi-user synchronous simulation game' extend the concept of a learning environment using the power and pace of communications technology to the workplace. They propose game-based learning environments for continuing professional development. Their multi-user synchronous simulated Dice Game for manufacturing training involves participants from different, dispersed locations in common problem solving tasks. The proposed learning environment explores real work situations in the context of a factory and encourages risk taking, which is safe and allows the learner to make mistakes and learn from them.

A number of common themes and perspectives explored in this Special Issue of *IJCEELL* come together in Despres and George's contribution, 'Computer-supported

distance learning: an example in educational robotics'. The authors discuss a distance learning environment that uses computer driven pedagogical micro-robots. Their learning environment, ROBOTEACH, provides a range of production tools for the design, construction, and programming of micro-robots. The ROBOTEACH project involves independent teams; communication tools enable them to interact between themselves and with a remote human teacher using synchronous and asynchronous devices. Finally, coordinating tools allow each team to manage and plan the project methodologically. Educational environments like ROBOTEACH appear to be promising for supporting life-long learning; they can be used for remote training of the workforce of small and medium-sized companies, which are interested in the further education of their employees.

The papers in this Special Issue of *IJCEELL* share a common optimism about the future role of ICT as the servant and not the master of society in the 21st century. The power and speed of communications technology should enable us to harness the effectiveness of information and communications tools to enhance and enrich all of our lives.