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Designing E-learning Interactions in the 21st Century: revisiting and rethinking the role of theory

ANDREW RAVENSCROFT

Introduction

In this article, I shall consider research and development in e-learning in terms of learning processes and interactions that are stimulated, supported and favoured by innovative educational technologies. I examine relationships between learning theory and interaction design by reviewing and critiquing a relevant selection of work that has been undertaken in the last 50 years. Implicit in this review is the development of an argument that emphasises the role of collaborative dialogue and discourse in the learning process, with particular reference to Vygotsky's theory of the development of higher mental processes. In evaluating the roles that computers can play in supporting effective educational interaction, the importance of dialogue models and dialogue games is proposed; and the implications which these paradigms hold for how we actually conceive of design are articulated.

E-learning: half a century of design

The notion that 'electronic learning' is a recent initiative is a popular misconception. Arguably, electronic learning (hereafter e-learning) started in the 1950s. We should be mindful of this and initiatives since then when we consider the current feverish interest and activity in exploiting maturing Internet technologies, particularly in the context of open and distance learning (ODL) and to design virtual learning environments (VLEs), on-line courses, virtual universities and the like. Are these initiatives properly exploiting the highly interactive, communicative and participative possibilities provided by contemporary technologies? Or are we simply replicating or augmenting 'conventional' approaches to teaching and learning, locally or at a distance, in ways that downplay the opportunity to re-evaluate 'what it actually takes to learn' and thus ignoring ways of developing more innovative and improved pedagogical practices.

I suggest that we should step back from the more practical and institutional concerns for a moment and focus on more fundamental issues concerning the learning processes and interactions that are, or can be, supported by innovative educational technologies. This focus is relevant to all levels of education. I argue that we cannot truly transform educational practice for the better through utilising new technologies unless we examine the roles the computer can play in truly stimulating, supporting and favouring innovative learning interactions that are linked to conceptual development and improvements in understanding. To assist us in this initiative, we should consider some important examples of relationships between learning theory and design which have occurred during the last half century of research and development in this field. Therefore, this article will review and critique a relevant selection of research and development in e-learning interaction that spans the last 50 years. Implicit in this review is the development of an argument that emphasises the role of collaborative discourse and dialogue in the learning process which stresses the relevance of Vygotsky's theory of the development of higher mental processes. Finally, I propose that we question the very role of theory in design. Should we conceive it, as is usually the case, as something that is external to design, or is better to conceive of 'design as theory'?

Changing Technologies, Changing Theories and Changing Minds

E-learning has not developed in a linear fashion over the past 50 years. As underpinning technologies have come and gone, so have implicated pedagogical fashions that have represented initiatives to exploit them. Similarly, the relationship between learning theory and the design of educational technology systems and activities has undergone a number of interesting changes which are also usually influenced by the available technologies. In brief, most e-learning initiatives have been technology-led rather than theory-led, although there have been some notable examples of a healthy symbiosis. This article focuses on some of these examples, and, through a critique, proposes a conception of e-learning interaction design for the 21st century

Learning as Shaping Behaviour

During the genesis of e-learning, educational technology researchers applied behaviourist ideas to the development of teaching machines, implementing Skinner's (1954) notions of operant conditioning through reinforcement schedules in the context of programmed instruction. Skinner believed that behaviour was shaped by the reinforcing consequences delivered by the environment to responses, or operants, made by the student. Therefore, the emphasis was given to designing an external environment which shaped behaviour through learner-system interactions. Typically, information was presented in brief chunks, followed by questions and *immediate* feedback that reinforced correct responses. Therein lay the main problem with the approach. Although correct behaviour was reinforced, incorrect responses, and even minor errors, such as misspellings or correct semantic substitutions, could not be dealt with because no diagnostic, explanatory or remediatory strategies existed in such systems. Further, there was no opportunity for reflection and intervention on the part of the student. Indeed, the implication was that such systems had been inadequately designed in not drawing an appropriate response from the learner in these cases.

To provide structure to the curriculum elements making up a learning programme, Gagné (1974) proposed a methodology of task analysis that enhanced both conceptual and procedural knowledge under his proposed framework of intellectual skills. This enabled the 'conditions' of learning, for achieving the attainment objectives, to be engineered, since his analysis provided advice on both the sequencing and types of instructions required to meet differing objectives. However, it soon became apparent that the interactions in these learning programmes were also too limited, and, in practice, the main focus was given to drill-and-practice. This involved adaptive but directed instruction which used informative feedback and performance decision rules to regulate the curriculum path.

Summing up, both these approaches were overly prescriptive, with little initiative being given to the students, who had no opportunity for reflection and 'higher level' thinking and reasoning. Learners are not *tabula rasa*, and so the knowledge and processes they bring to an educational interaction have a significant bearing on what and how they learn from these interchanges.

Recognising Cognitive Differences — Pask and his Colleagues

In parallel with Gagné, more cognitively oriented, learner-centred approaches to e-learning design were also developed. Based on Piagetian style experiments, the cyberneticist Pask and his colleague Scott (Pask & Scott, 1972) identified *serial*– step by step — and *holist* — global — learning styles, and subsequently developed the CASTE (Course Assembly System and Tutorial Environment) system to support both approaches. This gave students control over curriculum navigation and the types of material used in learning. In further experiments Pask and his colleagues constrained the system to support learning styles that mismatched the one identified for the learner and vice versa. He found that this mismatching produced inferior learning compared with trials that matched the learning style with the imposed interaction style. Although the concept of learning styles might be considered problematic, in that it cannot clearly predict consequences, it points out that students have preferred methods of interaction, and ideally, an e-learning system should accommodate this. Work with the CASTE system also furnished key input to a parallel strand of work, namely an approach to cognitive psychology known as 'the theory of conversations, individuals and knowables' (Pask, Scott & Kallikourdis, 1973; Pask 1975; 1976).

The most prominent feature of CASTE was the domain map, which allowed students to decide their own path through a topic, and hence, follow a route that accommodated their particular learning style. This was regulated by how much they knew, based on how much and what topics had been covered. Another interesting aspect was the way in which students using CASTE interacted with a topic that was represented as a node on the domain map. Students had the option to EXPLORE a node, AIM towards it, or make it a GOAL. Hence, they were encouraged to decide upon and make explicit their learning strategies.

Pask also suggested that, to fully exploit the serialist-holist dimension, conversational guidance needed to be introduced to ensure an appropriate mapping between learning styles and teaching strategy. This was because students may not be aware of their predominant learning style. Indeed, Pask viewed conversation as critical in both cybernetic and conventional teaching-learning contexts, stating:

> To summarise the matter, teaching systems ought to be conversational in form and so devised that strategies are matched to individual competence. (Pask, 1975, p. 222)

Continuing with this theme, Pask (1976) also proposed a conversational pedagogy called TEACHBACK, that has been considered by contemporary researchers (Ravenscroft, 1997; 2000; Ravenscroft & Hartley, 1999; Ravenscroft & Pilkington, 2000) in the design of intelligent argumentation systems that are discussed later.

A major contribution made by Pask and his colleagues was that, unlike the more behaviourist inspired approaches to design (Skinner, 1954; Gagne, 1974), they allowed more learner control of the interaction and hence facilitated different learning styles. They took account of cognitive individual differences such as the serialist-holist distinction, whilst still *guiding* and *structuring* the interaction by placing constraints on the path through the curriculum materials, thus achieving a blend of learner freedom and tutoring guidance on the part of the cybernetic system.

Cognitive Constructivism: Piaget, Papert and the creation of individual meaning

A more extremely cognitive and individualist approach to interaction design is the *constructivist* paradigm, which was developed and emphasised in the work of Jean Piaget. Although he did not follow either a rigid reductionist procedure or the information processing paradigm associated with mainstream cognitive psychology, his approach is commonly referred to as *cognitive constructivism*. The most engaging application of this theory to e-learning was delivered by Seymour Papert (1980) in his book *Mindstorms* and with the LOGO programming language that he developed.

According to Piaget, the child acts on the world, with expectations about consequent changes, and, when these are not met he enters into a state of cognitive conflict or disequilibrium. Thus, he seeks to retain an equilibrium state and so accommodates unexpected data or experience into his understanding of the context under exploration. In a sense, the child is conceived as a scientist (Driver, 1983), setting hypotheses and testing them by actively interacting with the world.

Inspired by these constructivist ideas, Papert (1980) developed the LOGO language, which allowed learners to create their own 'mental models' and microworlds and thus create individual meaning for themselves. So, as it was originally conceived, each child had 'their own machine', and LOGO was designed to prompt a purely learner-centred interaction in which the student 'told the computer what to do' and observed its response. It was a curriculum innovation, fostering 'learning by discovery', and allowing students to develop their own knowledge and understanding in a principled manner but without explicit guidance from a tutor — through devising their own curriculum of activities.

The central tenet of this approach relied on a computational metaphor. Learners expressed ideas as computer programmes that revealed their procedural knowledge and observed the consequences of their instructions in the form of dynamic displays running on the computer screen. To raise the level of abstraction of their descriptions, they used stored procedures that could become components of larger programmes. The procedures served as 'transitional objects' (Papert, 1980) that were 'objects-to-think with', and this was a major motivation for Papert. Also, because learning was unadorned with any tutoring involvement, the students imposed their own learning goals through experimentation and extensions of their procedures, thus developing their own curriculum of activities. To realise this computational metaphor for learning, LOGO provided the user with a procedural programming language, integrating standard programming concepts like *commands*, *variables*, *procedures*, *sub-procedures*, *programmes* and *recursion*. Using these concepts, the learners expressed their knowledge in the form of a procedural description that was subsequently run and represented in the more abstract form. It was this language, implementing Papert's computational metaphor, that allowed them to express and develop their 'powerful ideas' (Papert, 1980).

However, there were problems with this language as envisioned by Papert. Some students found its syntax awkward and difficult to use, and feedback comments, that could only be given by the system at the syntactic level, were not easy to interpret. This led to questions about the particularity of both the language and the computational metaphor it served to implement (Laurillard, 1993). In short, although learners could express their procedural knowledge and observe its consequences 'on the screen', this process was constrained by the representational schemes that were entailed by the computational metaphor, including the procedural programming language derived from it. Was LOGO an effective cognitive tool supporting conceptual development and learning? Or, was it the case that students thought in a 'LOGO way' only about LOGO itself?

An important finding from the evaluation studies (Sutherland, 1983; Hoyles & Noss, 1992) was that teachers who had used LOGO were skeptical about the value of *pure* discovery learning, because they needed to support the interactions directly, through guided discussions, or indirectly by providing worksheets. In defence of LOGO, Papert argued that most of the studies were flawed in their philosophy, measuring outcomes instead of examining the richness of the interactions and the learning process. Hence, he proposed an evaluation methodology in which experienced educators acted as 'theatre critics', observing and commenting on learning performance; a position attacked by Becker (1987) as unscientific.

Summing up, this work has shown that providing a language whereby learners expressed their ideas and procedural knowledge in a microworld that 'ran' the language to provide an 'active' abstraction, encouraging the development of novel ways of thinking and reasoning, was innovative. It found sympathy with many teachers. The facility for learners to structure their own interaction, and, via reflection on observed patterns of behaviour, to construct meaning and understanding for themselves, thus, reinforcing their own learning behaviour, was an interesting addition to the curriculum. However, the evaluation studies led to few clear conclusions about LOGO's educational value and, in cases where it was effective, guidance in the form of discussion or work-sheets was provided by the teacher. Crook (1994) argues that for an exploratory learning environment like LOGO to be effective there must be some tutoring guidance, but this should not be strongly *didactic*, but instead, more *interventionist* and *supportive*.

Releasing and Refining Learners' Knowledge through Modelling and Explanation

In addressing criticisms about the particularity of procedural languages like LOGO (Papert, 1980), a modelling community (Mellar *et al.*, 1994) provided less idiosyncratic languages that allowed learners to express and construct their own explanatory models of 'real' situations. Whereas LOGO was an experience in which a procedural language *runs* abstract representations, modelling languages represent and *run* analogues of 'actual' systems. The general view that modelling is a means to elicit, construct and represent explanations and ideas that need to be subsequently evaluated and reconstructed as part of the educative process makes it an interesting and important e-learning initiative.

A particular focus for the modelling fraternity is semi-quantitative reasoning. They argue that it is a relevant and naturalistic learning process, which is not suitably addressed in the curriculum. The term 'semi-quantitative' entails the notions of direction and approximate size of causes and effects, which distinguishes it from the notion of purely qualitative reasoning. The approach is summed up by Joan Bliss:

> Semi-quantitative modelling is new and important. It involves thinking about systems in terms of the rough and ready size of things and directions of effects, for example, ... (Bliss, 1994a, p 117)

A particular focus in semi-quantitative reasoning and qualitative modelling is the notion of *causality*, which, according to Bliss, is often expressed as:

> ... an action performed by an agent in order to bring about an event or a state of affairs, that is, an agent performing an action with the expectation or intent that something will follow; ... (Bliss, 1994a, p. 117)

Here, the treatment of causality is more in line with Piaget's ideas than those of normative philosophy. Piaget understood causality in the wider sense, distinguishing lawfulness and causality. According to him, 'laws' represent more general relations between objects or events, whereas causality includes necessary relations. Thus, Bliss (1994a) takes a similar view to Pat Hayes (1985) in the context of artificial intelligence (AI):

> Causal reasoning may be simply a family of inferences whose properties will vary according to the content of the argument. (Hayes, 1985, in Bliss (1994a) p. 118)

Also, the approach accepts that the elicitation and representation of 'incorrect' causal reasoning has interesting pedagogic implications in itself. It was with the aim of eliciting and representing semi-quantitative learner reasoning that the software system IQON was developed.

IQON was a general modelling tool, allowing learners to represent systems consisting of interacting variables, where qualitative values represented relative quantity change relationships between the variables (e.g. 'make it bigger', 'make it smaller') and the magnitude of variables (e.g. small, normal, big). The variables were represented by defining 'boxes', linked by arrows displaying mutual effects using either a plus or minus sign to convey direction of effect. A level indicator on each box allowed the magnitude of the variables to be observed and altered, and a normal level — in the middle — meant there was no effect on the connected variables. Thus, by using IQON, the learner could create a network of interconnected variables and observe how changing the level of one variable changed others, and 'rippled through' the model. Experiments using IQON (Bliss, 1994b) to evaluate how it could facilitate or improve reasoning about a number of domains yielded interesting results.

The evaluation studies showed that students had difficulty understanding indirect effects of variable manipulations, tending to concentrate on links between pairs and not take a more *abstract* view of the model as a 'system'. Secondly, students paid great attention to observing the model functioning 'on the screen'. They were described as 'fascinated' by the activity but with 'non-causal reasoning dominating their commentaries' (Bliss, 1994b). In brief, they had difficulties interpreting and understanding the models they had constructed. However, it was noted that predictions became more causal towards the end of the task, especially, and not surprisingly, when students explained *why* certain results were obtained. So, it was, actually, a useful discussion tool that mediated educational dialogue.

A methodological problem with these studies was that they did not disambiguate what occurred due to the interaction between the learner and system from the activity prompted by the researcher. Similarly, other studies (Hartley, 1998) have shown that, without prompting from a tutor, learners often show little willingness to explain outcomes at a conceptual, causal level. These points are particularly important when we move from modelling domains that are reasonably straightforward to ones that are characterised by competition between *alternative conceptions* (Driver, 1983) and that need to be delineated and overcome — often, by addressing underpinning conceptions — to achieve a correct explanatory model.

To address this problem, another project investigating conceptual change in science (Twigger, *et al.*, 1991) used a qualitative modelling language called VARILAB in concert with a simulation called DM3. The latter provided a 'correct' world model of Newtonian physics, and the idea was that learners experimented with simulation scenarios that followed correct scientific principles, and hence, became familiar with, and experienced, a correct 'world view'. Then, they expressed the knowledge and understanding that they had acquired through modelling the same scenarios using the VARILAB language.

VARILAB had notions of cause-effect or agency and was loosely related to the Qualitative Process Theory developed by Forbus (1984). The Objects were named and described by a set of attributes (e.g. mass, speed, colour) and their associated values. The causal agents brought changes to the states of objects according to a 'law of effect'. These object-agent connections were specified through drawing a causal link and specifying the attribute affected by a monotonically increasing or decreasing relation (e.g. speed, increase). To complete the description, a size of effect (from very small to very big) had to be included. The output from executing the model was shown as an animated ticker-tape or in graphical form for the attributes specified by the learner.

The Necessity for Tutoring Dialogue

During the VARILAB modelling exercises it was hoped that, in the classic Piagetian way, students would match their hypothesis and expectations against the perceived output to confirm their explanatory models or prompt reflection, accommodation and reconstruction. In general, the experiments were successful in inducing adaptive conceptual change for most reported misconceptions, but the tutor-experimenter had to play a more active role than was anticipated (Hartley, 1998). These results clearly demonstrated the need for collaborative argumentation with a tutor, or 'more learned other', to stimulate and support appropriate conceptual change and development through directed lines of argument and reasoning (Ravenscroft, 2000).

Partly inspired by these findings, another study was conducted as part of a project called DISCOURSE (Tait, 1994; Pilkington & Parker-Jones, 1996) which investigated reasoning and reflective activities under two interaction conditions, namely a student-student-tutor and a student-tutor condition. The aim was to discover the extent to which self-questioning and reflective reasoning were prompted by participants, and, in turn, the influence of these activities on learning outcomes. The domain of study was calcium homeostasis (i.e. the regulation of calcium in the human body) and the simulation that was used consisted of a quantitative model with a Hypercard interface. This resulted in a model that followed the metaphor of an entity-relation flow diagram incorporating stocks, regulators, converters, sources, or sinks. The role of the tutor was critical and similar in both conditions; they provided *no* knowledge about calcium homeostasis, but they maintained a facilitating, *inquiry* style dialogue (Pilkington & Mallen, 1996) characterised by reflecting questions back to students, hinting, prompting, and requesting either explanations or justifications for actions.

It was found that, although the amount of causal prompts made by the tutor was approximately equal in both conditions, the single student — in the one-to-one situation — responded with more reasoning, self explanation and reflection style utterances. In comparison, the paired groups spent more time monitoring their joint progress, making observations and negotiating what to do next, concentrating less on reasoning and explanation. The finding that a tutor can apparently increase the amount of reasoning, self explanation and reflection to improve problem solving and performance by *not* answering questions, but by reflecting inquiries back to students, carries interesting implications for designing dialogical e-learning systems. Following further discourse analysis of the data, Pilkington & Mallen (1996) identified and proposed *inquiry* and *debating* dialogue games (Levin & Moore, 1977; MacKenzie, 1979; Walton, 1984) for effective collaborative dialogue.

Summing up, these studies demonstrated the need for a collaborative dialogue with a tutor, or 'more learned' other, which included dialectical features. This shows the relevance of Vygotsky's notions about learning and the development of higher mental processes.

Social Constructivism: Vygotsky and the role of dialogue with a more learned other

Vygotsky's theory of the development of higher mental processes helps to explain the results of the above studies and also provides a foundation and inspiration for many contemporary approaches to e-learning that emphasise the necessity for collaborative, argumentative and reflective discourses. He conceived learning as an instructional process aimed at transforming the mind of the child into that of an adult and treated the role of language as primary in this process, with the relevant activities performed primarily in school. However, it is accepted that his ideas are not limited to relationships involving strictly schoolchildren and adult teachers, but more appropriately, to any relevant context involving a learner and a more learned other. Similarly, his theories are not bound to the 'traditional' concept of a school. Nevertheless, I will retain his original taxonomy to retain authenticity for the purpose of this article.

Vygotsky draws a clear distinction between lower level mental processes, such as elementary perception and attention, and higher level mental processes that include verbal thought, logical memory, selective attention and reasoning. He argues for a qualitative distinction between these two levels of mental performance, because unlike lower level activity, the higher level is: mediated through cultural symbols and tools; self-regulated rather than bound to a stimulus context; social in origin; and, the result of conscious awareness rather than an automatic response.

Critical in distinguishing higher and lower level activity is the qualitative developmental transition that occurs when language, or any other sign system, is internalised to operate as a mediating factor between environmental stimuli and an individual's response. This mediation *transforms* the lower level activity by *lifting it onto a higher plane* and can be achieved through the application of material or psychological tools. Further, in using such tools we become conscious and in control of our mental activities. However, Vygotsky considered language to be the most interesting and powerful of these semiotic mediators and the primary tool for thinking. He claims that these higher mental functions originate in the social, and development proceeds 'from action to thought' and therefore communication and social contact are essential. It is through the communicative process that external sign systems conveying interpersonal communication become internalised to operate as intrapersonal psychological tools that can *transform* mental functioning. In other words, internal language and thought are transformed from the 'outside'. This idea is critical to Vygotsky's notions about conceptual development and the evolution of linguistic meaning as the mind of the child evolves into that of an adult.

A problem during conceptual development stems from the tension between two different forms of experience that give rise to two interrelated groups of concepts that Vygotsky called *scientific* and *spontaneous*. Spontaneous concepts arise out of everyday experience and so they are rich in contextual associations but unsystematic, following a 'common sense' logic and expressed in an informal language. In contrast, scientific concepts originate during highly structured activity within the culturally coordinated practices of a school. Teachers possessing a received, authentic knowledge of a subject — that is organised, systematic in its reasoning, and because of its more abstract language, less dependent on contextual reference — assist in enculturating the learner with their scientific knowledge and understanding. According to Vygotsky, it is critical during schooling to develop the concrete, spontaneous concepts held by the child into abstract, scientific concepts representative of adult understanding that is the content of the curriculum. However, he argues that instruction should *stem from the scientific concepts and not build on the spontaneous ones, arguing that mental* *development does not precede instruction but depends on it*. Therefore, by 'starting from' the more abstract scientist's view, and using cooperative dialogue, the teacher develops the child's spontaneous concepts into scientific conceptions. The primary theoretical construct introduced by Vygotsky for 'engineering' this conceptual change is the zone of proximal development (ZPD). According to Vygotsky (1978), the ZPD represents the place where the child's empirically rich but disorganised spontaneous, or contextual, concepts meet with the *systemacity* and logic of adult reasoning. It is:

> . . . the distance between a child's actual developmental level as determined by independent problem solving and the higher level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers. (Vygotsky, 1978, p. 86)

Through tasks, exercises and dialogue within the ZPD, the weaknesses of the child's spontaneous concepts and reasoning are made explicit and compensated for by the strengths of the adult's scientific conceptions and reasoning. Thus, in performing the task, the child 'appropriates' the more adult, scientific conceptualisations and becomes socialised into the expert practitioner's knowledge and approach to particular problems, subsequently operating as a mature adult. The notion of the ZPD is also a positive and powerful paradigm for evaluating and improving the teaching-learning process. Failure to complete a task successfully can be evaluated in terms of what 'extra' should be introduced to improve the ZPD, instead of simply assessing a 'failure' in performance.

In fact, Vygotsky shared many of Piaget's ideas about conceptual development, but treated social interaction and tutoring dialogue and interventions as critical factors. Commenting on Piaget, Vygotsky points out:

> Our disagreement with Piaget centers on one point only, but an important point. He assumes that development and instruction are entirely separate, incommensurate processes, that the function of information is merely to introduce adult ways of thinking, which conflict with the child's own and, eventually, supplant them. Such a position stems from the old psychological tradition of separating the structural from the functional aspects of development . . . Studying child thought apart from the influence of instruction, as Piaget did, excludes a very important source of change and bars the researcher from posing the questions of the interaction of development and instruction . . . (Vygotsky, 1962, pp. 206–7)

Indeed, whereas Piaget is considered a *cognitive constructivist*, Vygotsky is considered a *social constructivist*, and summarising, he made the following points that are relevant to designing e-learning interactions. First, learning, and particularly the development of higher mental processes, requires a cooperative interaction between a student and a more learned other, where the latter may be a human tutor or an intelligent computer system. Secondly, learning is engineered by shifting the learner's zone of proximal development, which can be achieved via a collaborative dialectic maintained between the learner and a tutor or system. Thirdly, meaning — in the head — derives from the social context and the interaction, so the learner develops a conceptual understanding 'through' dialogue. Or, putting it another way, 'thought follows action'. Finally, language is considered the primary mediator of thought and a tool for thinking, so the external dialectic processes engaged between interlocutors becomes internalised to provide improved reasoning and reflective capabilities.

In considering the requirement for a tutoring dialogue in the context of Vygotsky's work, this leads to a critique of dialogic tutoring systems in terms of the degree to which they supported effective educational dialogues. How did these systems model features of effective tutoring dialogue? And to what degree was the computer an effective tutor or more learned other?

Intelligent Dialogue Systems: computer-based tutors?

The field of intelligent tutoring systems (Wenger, 1987) has delivered a number of initiatives that have modelled and maintained a tutoring discourse. Unfortunately, this research has pointed out how difficult successful computer-based dialogic tutoring actually is (McCalla, 1993). Whereas many natural language understanding applications assume the user has a more or less stable understanding of the subject, sufficient let's say, to answer questions, a problem in modelling tutoring dialogues is that the learner's knowledge and understanding evolve as the interaction proceeds. Meaning arises from the interaction. As far as the syntactic, semantic and pragmatic (or contextual) dimensions are concerned, there seems to have been a movement towards an emphasis on pragmatic aspects that are particularly important in effective tutoring dialogue. Pragmatic level features include the use of particular speech acts (or moves), the relative roles of the interlocutors and dialogue strategies and tactics adopted by the tutor. In fact, the developments in dialogic tutoring systems can be classified according to the degree to which they address pragmatic issues in general and pedagogic strategy in particular. A selection of tutoring systems that were based on a dialogical pedagogy will now be discussed in line with these pragmatic level issues.

Socratic Tutoring with SCHOLAR, WHY and GUIDON

A number of early intelligent tutoring systems (ITSs) aimed to teach the learner using a 'Socratic dialogue' derived from discourse analysis of human tutoring, in order to 'teach' a subject and foster the acquisition of generic reasoning skills. SCHOLAR (Carbonell, 1970) and WHY (Collins, 1977) used the method to teach South American Geography and causal reasoning respectively. However, although these systems had good semantic and syntactic natural language properties, they had limited or 'shallow' strategic knowledge, that remained, to a large measure, unprincipled.

By building on the work of SCHOLAR and WHY, the GUIDON (Clancey, 1987) system, which taught medical decision making, attempted a complete separation of domain and pedagogical knowledge to facilitate experimentation with different dialogue strategies. GUIDON held a convincing natural language dialogue and made an advance on pragmatic dialogue aspects through this segregation of domain and tutoring knowledge, whilst prompting and allowing student control of topic selection. Hence, the student became a more active participant in the learning process. According to Woolf (1988), GUIDON was one of the few systems to communicate effectively with students. However, as with SCHOLAR and WHY, it faced criticism about the lack of any *clear* pedagogic principles (Wenger, 1987) manifested as dialogue strategy. Clancey (1987) admits that the tutoring rules were actually based on 'intuitive' teaching ideas. So, although GUIDON separated tutoring knowledge from domain knowledge and modularised it to serve specific goals, as is typical in rule-based systems, the rules evolved incrementally, and clear pedagogic principles were not embodied, nor did they emerge. In short, the strategic knowledge that guided the dialogue was still too shallow.

Learning through Knowledge Negotiation and Collaboration

In contrast, Michael Baker (1989) proposed a model for interaction design that made the student a more active participant who negotiated with the system to decide the dialogue strategy. This was one of the first attempts to explicitly address pragmatic, or 'higher-level dialogue' issues within the KANT (Kritical Argument Negotiated Tutoring) system. It was an exemplar prototype of the general approach of Negotiated Tutoring (Baker, 1989; 1994) applied to the domain of music. KANT implemented the main features of the Negotiated Tutoring approach and held a convincing negotiative dialogue about the goals of the interaction (Baker, 1992), despite using canned text and keyword responses, usually prompted by the system. Although there was a limited number of dialogue moves, namely 'claim' and 'challenge', the system's fundamental philosophy, to hold a negotiative dialogue for a domain characterised by, and represented as 'uncertain and incomplete partially justified beliefs' was a significant step forward. The KANT model accepted that students had a role to play in deciding the goals of a learning interaction, and subsequently, what aspect of the domain knowledge they wanted to learn. This is important because, as Moyse & Elsom-Cook (1992) pointed out:

> It has been realized that for many domains there is not a single correct representation, and that the interpretation of the domain or 'viewpoint', must be jointly constructed between teacher and learner. (Moyse & Elsom-Cook, 1992, p 1)

However, we must be cautious about prescribing negotiation in the wider context of collaborative interactions because, in some circumstances, it may be an inappropriate instructional paradigm. Pilkington & Parker-Jones (1996) demonstrated that collaborative problem solving partners spent time negotiating what to do at an operational level to the detriment of reasoning and reflection on problem solving. Furthermore, in KANT there was no way to evaluate the validity of domain level propositions. Baker pointed out:

> KANT is limited by the fact that there is no understanding of the student utterances — propositions are simply compared and 'contrasted' . . . (Baker, 1992, p. 231)

Without any evaluation of the 'consistency' of learners' knowledge and understanding, a system remains passive, unable to question the validity of learners' beliefs or prompt them to further refine their conceptual understanding.

In short, a prescriptive model is usually required to provide a position to argue from, and subsequently 'lock horns' in ways that stimulate reasoning that leads to the revision and refinement of knowledge.

Learning through Argumentation and Constructive Conflict

In contrast to Baker's (1989) system, a more radical approach to instructional epistemology and tutoring strategy existed in the systems which actually opposed the learner's beliefs (Bloch & Farrell, 1988; Retalis, Pain & Haggith, 1996), without necessarily evaluating their 'validity', to support the learning of argumentation skills and competitive debate. The designers of these systems were more interested in supporting the acquisition of dialectic knowledge rather than domain knowledge and their strategies supported this aim. DECIDER (Bloch & Farrell, 1988) followed a case-based problem solving paradigm for American foreign policy, constructing counter arguments to the students' solutions, justified by alternative paradigm cases illustrating a different outcome. Unfortunately, this led to an epistemically narrow interaction. Students concentrated on pointing out differences between their solution and the counter example without questioning the system's case or position at any higher level. Hence, it was questionable whether they actually internalised the structure or process of argument.

A more recent approach to teaching argumentation skills and tutoring in controversial domains in general adopted a more sophisticated approach to argument structure. The OLIA (Retalis, Pain & Haggith, 1996) system used a *domain independent* meta-level argumentation framework (Haggith, 1995) to play both a Coaching and Devil's Advocate Strategy with the learner. Within this framework, it was accepted that, although low-level representational expressiveness of propositional content was lost, this was compensated for by a rich, higher-level representation of structure in the form of interpropositional connections. By applying the Devil's Advocate Strategy, the system aimed to explore inconsistencies instead of removing them. Unfortunately, OLIA could support only limited interactions, the 'Devil' could only use one type of move and students could not add their own propositions.

In contrast, DIALAB (Pilkington, Hartley, Hintze & Moore, 1992) provided a range of dialogue moves represented in a dialogue game (MacKenzie, 1979; Walton, 1984) interface to support learning skills of competitive debate and provide a framework for *managing* a dialectical interaction. However, the DIALAB system had no domain or strategic knowledge, so it could not argue with the learner, instead it mediated an argument between two participants within the strictures of a particular dialogue game called the DC Dialogue Game (MacKenzie, 1979). This approach raises questions about the relationship between argument, reasoning and understanding. It may be satisfactory for domains characterised by 'uncertain and incomplete partially justified beliefs' (Baker, 1989), where there is little consensus about 'correct' or 'incorrect' knowledge. However, it is probably inadequate for domains where there is some consensus about 'correct' knowledge, and therefore the need for some specification or acquisition of knowledge by the system.

However, later work has integrated domain knowledge within a dialogue game approach (Ravenscroft & Hartley, 1999; Ravenscroft & Pilkington, 2000). In particular, recent research by Ravenscroft (1997; 2000) has developed a computer-based pedagogy and approach to interaction design called 'learning as knowledge refinement' that is based on a Vygotskyan approach to discourse and dialogue and empirical studies (Hartley, 1998). The central thrust was to stimulate and support conceptual development in science. It also aimed to promote the use and acquisition of reasoning and conceptual skills through the internalisation of dialectic processes arising through structured educational argumentation. The approach was validated by designing a system called CoLLeGE (Computer based Lab for Language Games in Education), which has a clear pedagogic strategy linking a generic domain model to a repertoire of dialogue tactics. CoLLeGE was developed by incorporating discourse analysis, dialogue game and artificial intelligence techniques within a methodology of 'investigation by design' (IBD). This general methodology for designing implementation independent dialogue models for e-learning is described in detail in Ravenscroft & Pilkington (2000) and elaborated below.

Socio-cognitive Approaches: discourse analysis and dialogue games

Given that theories of learning (Vygotsky, 1962; 1974) have suggested that dialogue has an important role to play in shaping conceptual development, many contemporary researchers have asked some specific questions such as: what kinds of dialogue and what kinds of social interaction, or group settings and tasks, are important in determining when such processes will be successful in yielding meaningful conceptual change or the development of transferable reasoning skills? Answers gained from empirical investigation have as yet been partial (Edwards & Mercer, 1987). Moreover, as a result of developments in Computer Mediated Communication (CMC) within the context of emerging Internet technologies, new questions have been generated on the ways differences between communication with and through computers alter interaction and might, hence, impact upon learning outcomes (Littleton & Light, 1998). There is, thus, a need to further examine the features that make educational dialogue effective in ways that inform the development and use of systems that support e-learning.

Although there remains widespread debate as to the form dialogue should take to facilitate conceptual development, research which adopts discourse analysis techniques is beginning to suggest when and why tutoring talk might be particularly helpful. From work investigating natural educational dialogues that aim to change student conceptualisations in a variety of situations, some consensus is beginning to emerge as to the strategies and speech acts (sets of moves) which are likely to be important.

For example, using the DISCOUNT Discourse Analysis scheme (Pilkington, 1999), which includes Exchange Structure, Move (Speech-Act) and Rhetorical analyses, it is possible to determine which participants are active in dialogue and how. DISCOUNT has been used to give insights into collaboration in natural and CMC dialogue contexts (de Vincente, Bouwer & Pain, 1999; Pilkington, Treasure-Jones & Kneser, 1999). From these and similar studies there is evidence that 'successful' exchanges are more likely to include clarifying, challenging and justification moves. Mercer and Wegerif (1999) refer to 'exploratory talk', others refer to argument or 'constructive conflict' (Kuhn, Shaw & Felton, 1997); these moves are significant in both. Another move that is often associated with successful exchanges is hinting. From a more detailed analysis of the co-occurence of these speech acts and their position within exchanges we can begin to suggest common strategies for directed lines of reasoning which tutor and student(s) engage in (Katz, 1997).

The studies described above all suggest the potential of dialogue analysis for revealing important insights into educational argumentation and collaboration that can be fed into interaction design. However, there is much still to investigate both in natural and CMC contexts before we can be confident about the relative importance of the factors discussed above or the reliability of these findings (Chi, 1997). Yet, given the role of dialogue in conceptual development, there is a pressing need to develop intelligent systems and interfaces that can engage their users in such discourses. A more direct approach to this problem, mentioned earlier, is the methodology of *investigation by design*, proposed by Ravenscroft & Pilkington (2000). This combines discourse analysis and dialogue game techniques to specify formal dialogue models implemented as intelligent dialogue systems. A central tenet of this approach is to take some of the features of successful dialogue — as yet not fully proven to be effective — and actively design them into interaction scenarios aimed at supporting learning. Once these models have been developed, we can evaluate their effectiveness, and systematically vary the roles, strategies, tactics and moves adopted to further explore the utility of these features in guiding learners towards more systematic reasoning.

The DISCOUNT discourse analysis scheme describes many different moves and rhetorical relations seen in dialogue and provides a useful abstract representation of these features. By re-combining these features at different levels, different strategies for supporting learners through interaction can be modelled. However, to build suitable dialogue models, DISCOUNT type descriptions have to be made prescriptions and combined with decision making processes to plan turns. Moreover, in order for such planning to be made possible, the systems need to be able to categorise input according to its speech-act function. Dialogue game theory (MacKenzie, 1979; Walton, 1984), that was mentioned earlier, is the design paradigm that enables this.

Research investigating and examining the suitability of this approach has been ongoing for the past ten years (Pilkington, 1992; Pilkington, Hartley, Hintze & Moore, 1992; Moore, 1993; Ravenscroft, 1997; Pilkington, 1999; Burton, Brna & Pilkington, 1999; Ravenscroft, 2000; Ravenscroft & Pilkington, 2000). These projects have shown that dialogue game theory (Levin & Moore, 1977; MacKenzie, 1979; Walton, 1984) can be used as a software design paradigm for types of computer-mediated and computer-based argumentation dialogue in educational contexts. Here, the notion of a game is used to characterise and specify discourse in terms of the goals of the interlocutors (e.g. the elaboration of knowledge, the co-elaboration of knowledge, supporting or winning an argument), the relative roles of participants (e.g. inquirer, critiquer, explainer) and the types of dialogue tactics and moves that are performed (e.g. Assertion, Challenge, Withdraw). Also, rules govern the types of moves available to participants, the effect these have on commitment — to beliefs — and issues of initiative and turn-taking. Note that, in focusing on pragmatic level knowledge, these projects have not needed to directly address issues of semantic and syntactic level natural language processing and generation that have been examined by Pilkington (1992) and Pilkington & Grierson (1996).

Projects adopting this approach have produced a number of successful designs. They have shown that a model of collaborative argumentation — a *facilitating* dialogue game — supports and stimulates conceptual change and development in science (Ravenscroft, 2000; Matheson & Ravenscroft, 2001). And a model of fair and reasonable debate — a DC dialogue game — can be used to teach generic reasoning skills for debating controversial subjects (Pilkington, *et al.*, 1992; Moore, 1993). The former dialogue game has been implemented in the 'intelligent' computer-based dialogue system called CoLLeGE and the latter model has been implemented in the DIALAB computer-mediated argumentation system that was described earlier. Another project called CLARISSA has used dialogue games to implement a computer modelling 'laboratory' for investigating collaboration (Burton, Brna & Pilkington, 1999).

A major advantage of the dialogue game approach is that it allows us to incorporate rules and constraints into the design of communicative interactions that are consequently structured and managed along the lines we prescribe. Therefore, these systems can act as powerful cognitive and mediational tools that guide the dialogue and lines of reasoning in ways that lead to improvements in individual or shared knowledge and understanding.

Other research has demonstrated how dialogue game theory can represent a range of dialectical discourse genres (Maudet & Evrard, 1998; Moore & Hobbs, 1996), include multimedia features (Moore, 2000) and be adapted to take account of multi-user polylogues (Maudet & Moore, 2000). With regard to the latter, work in Computer Supported Collaborative Argumentation (Buckingham-Shum, 1999; Veerman, 1999) is beginning to take account of dialogue game theory.

However, in evaluating and deploying these dialogue games (Matheson & Ravenscroft, 2001; McAlister, 2001), the relevance of the broader, socio-cultural context is becoming increasingly apparent. We cannot hold a serious and engaging educational dialogue with anyone, about any subject, at any time. Instead, we also need to consider the socio-cultural context for discourses. Activity theory is a theoretical framework that is beginning to help us in this respect (Nardi, 1996; Engestrom, 1987; Barros & Verdejo, 2000).

Activity Theory: learning processes in a social, cultural and historical context

Activity theory is a development of Vygotsky's (1974) work that provides a framework for learning and development which accepts that meaning arises and evolves during interactions that are influenced by the social relations within a community of practice. Or, 'you are what you do' (Nardi, 1996, p.7) in a natural context that is influenced by history and culture. Hence, human practices are conceived as developmental processes 'with both individual and social levels interlinked at the same time.' (Knutti, 1996, p. 25).

An activity is considered the minimal meaningful context for individual actions, which means they are not rigid and static, but continuously changing and developing. These activities contain various artifacts, such as signs, methods, machines and computers, that serve as mediational tools to facilitate the operationalisation of conceptions in ways that lead to 'higher levels of thinking'. In achieving this, the mediational processes involving subjects and tools are directed towards objects, or objectives, and in transforming the objective into an outcome there is motivation for performing the activity. The addition of another 'level' that links the subject and the community and the objectives and the community is also included to complete the basic structure of an activity (Engestrom, 1987). Here, the relationship between subject and objective is mediated by tools, the relationship between subject and community is mediated by rules, and the relationship between objective and community is mediated by the division of labour. Therefore, this framework is essentially holistic. It emphasises relationships between interactions, processes and outcomes and the relevance of social conditions, such as a shared enterprise and the need for mutual engagement of conceptualisations. Therefore, the relevance of conceptual similarities and differences and changes and developments over time are taken into account in the design of mediated activities.

Isroff & Scanlon (2001) have reviewed activity theory in the context of computer-supported collaborative learning and reconsidered some of their previous studies using this framework. They conclude that, as it stands, it is more useful as a framework for describing and communicating findings than as a framework for uncovering 'further insights' into designing and interpreting collaborative learning activities. Similarly, although Baker *et al*, (1999) have used it to analyse different forms of grounding in collaborative learning, and Lewis (1997) has used it to research interdependent parameters in distributed communities, its value as a more prescriptive design paradigm for e-learning remains open to question.

Nevertheless, this and other research (Tolmie & Boyle, 2000) have demonstrated that an activity theory framework does hold some genuine value in shifting our attention to the relevance of social, cultural and historical influences and relationships that are implicated when we introduce and use innovative educational technologies. They have also highlighted the complexities associated with the way a design is operationalised within a context and how its use develops over time, and pointed out some of the limitations in the theory that need to be addressed.

Implications for E-learning in the 21st Century: models and methodologies

So, in considering the last 50 years in terms of the relationships between learning, or pedagogical theory, and interaction design, what can we conclude about designing e-learning in the 21st century? Research and development that clearly links theory to design has been piecemeal, and yet, delivered interesting and innovative educational activities. However, in evaluating these e-learning systems, we have usually learned more about the learning process itself than about how to optimise instruction. This is encouraging for researchers, but may be discouraging for practitioners who are looking for straightforward answers to their questions such as: what is the best way to teach x? Shall I use a simulation or should I carry on lecturing? The answer to which is invariably, 'I don't know, let's have a close look at what you and the students are actually doing, and then we can decide.' And where, typically, this will involve devising an innovative activity implicating new technology that is an addition to the curriculum — that requires re-thinking current, or conventional, practices to ensure careful integration (Ravenscroft, Tait & Hughes, 1996). But is this really surprising, given that the link between current educational practice and learning theory is arguably quite weak. Perturbing the instructional process through introducing new e-learning initiatives is bound to raise questions about 'what it actually takes to learn', and I argue that forcing the consideration of this issue is an invaluable contribution in itself.

In considering the contemporary learning contexts, maturing Internet technologies are providing an unparalleled technological foundation for designing innovative interactions that are highly engaging, communicative and participative. As these technologies become increasingly flexible, adaptive and robust there is an increased role for theories and models of learning to assist us in re-thinking learning and instruction. *Methodologies* that truly link models of learning to system designs are beginning to emerge. Ravenscroft and Pilkington (2000) have proposed 'investigation by design' (IBD) to formally render models of discourse into cognitive tools supporting effective educational dialogue. And they propose dialogue games as an implementation independent design paradigm for designing such systems. Along similar lines, Cook (1998) has proposed a Knowledge Mentoring framework (KMf) that links theory and interaction analysis to the design of pedagogical agents for 'open worlds'. These and similar approaches are important, because unlike many currently fashionable CMC approaches, they do not treat the computer as a mere conduit of discourse but as a powerful mediational tool that can support and promote the development of higher mental processes by designing interfaces that structure discourse and dialogue in ways that stimulate, support and favour learning.

These approaches are also addressing the need for a 'science' of learning technology design, which incorporates an *implementation independent* '*design level*'. This is an important advantage of current dialogue game approaches. Given that the pace of change of educational technology is unlikely to slow down, the need for relatively more stable and theoretically founded interaction models is becoming increasingly important. These models can be developed and tested systematically, irrespective of technological changes and trends (Matheson & Ravenscroft, 2001).

In arguing for the above we are aiming for a much closer fit between learning theory, design, implementation and evaluation in educational technology research and development. One way to interpret this emphasis on theoretically founded and testable dialogue models is that we are actually treating '*design as theory*'. That is, we are considering learning theory, technology and context in the design of educational interactions, in ways that treat designs, like theories, as something that are developed, validated, evaluated and refined rather than 'delivered'. These models are also prescriptive, so we can generate predications about the impact on learner knowledge and behaviour, whilst still evaluating their effectiveness and identifying unanticipated uses and advantages, rather than just 'trying them out and seeing what happens'.

This perspective does not discount the role of other learning theories that are 'external' to design initiatives. Instead, it proposes a working methodology that accepts that the scope of a design does not automatically generalise across contexts, but can be evaluated and systematically developed to address differing situations as there will be identifiable 'family resemblances' (Wittgenstein, 1953) between dialogue contexts.

In conclusion, as technologies and the practices that exploit them are unlikely to get less complex in the foreseeable future, I argue that we need to be more flexible and creative about the design process itself. Rational, deterministic methods for technological development and exploitation are becoming increasingly inappropriate. Instead we need to accept that we have to 'think hard for a while, build something and try it out, and then look closely and think again'.

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