Cook, J. *The role of dialogue in computer-based learning and observing learning: an evolutionary approach to theory*
Journal of Interactive Media in Education, 2002 (5)
[www-jime.open.ac.uk/2002/5]

Published
25 July 2002

ISSN: 1365-893X

# The role of dialogue in computer-based learning and observing learning: an evolutionary approach to theory

**John Cook**

## Abstract:

This paper examines two sides of a coin that relate to learning from dialogue. The first side of our coin relates to the role of dialogue in learning; the second side is related to the part that observations of learning dialogues can play in the design of computer-based learning environments. In order to define the scope of the paper, various complementary research question are examined. For example, one question is how and why does one learn from dialogue? A second question is how, or to what extent, can theories and studies of dialogue and interaction be exploited in a concrete way by designers of interactive media for education? Following a review of related literature I present my main argument, namely that the evolutionary approach provides a model by which research in learning, teaching and theories of interaction can jointly feed into the design process of learning technology. This is followed by an exposition of the evolutionary approach. There are three aspects to what I am terming an evolutionary approach to learning technology theory: (i) theories/models of teaching, learning and interaction, (ii) empirical observations of learning, and (iii) interactive learning environment design and implementation. The purpose of this evolutionary approach is the mapping out of not a specific theory, but how people are working towards the creation of theories. The evolutionary approach involves a constant process which slowly takes the educational technology field forward in iterative steps. In order to concretise the evolutionary approach, I examine the work of selected researchers, in the field of dialogue in learning, in the context of the identified three points of evolution. I conclude by suggesting that the evolutionary model can help designers of, and researchers into, learning technology in various important ways.

## Commentaries:

All JIME articles are published with links to a commentaries area, which includes part of the article's original review debate. Readers are invited to make use of this resource, and to add their own commentaries. The authors, reviewers, and anyone else who has 'subscribed' to this article via the website will receive e-mail copies of your postings.

**Keywords:** learning technology theory, learning through dialogue, dialogue analysis and modelling, interactive media design, meta-analysis

John Cook, *Learning Technology Research Institute, University of North London, London, N7 8DB, j.cook@unl.ac.uk*

## 1 Introduction

This paper examines two issues that relate to learning from dialogue. The first issue concerns the role of dialogue in learning. The second issue pertains to the role that observations of learning dialogues can play in the design of computer-based learning environments. In this paper I argue for an evolutionary approach to examining theory. What this paper does not try to put forward is one theoretical basis for learning technologies. The purpose of the evolutionary approach presented below is, rather, to provide a primarily descriptive tool that enables us to map out how different researchers are working towards the creation of theories, i.e. a tool for meta-analysis. The evolutionary approach is a useful, if somewhat simplified, conception of the role of theory and models in learning technology development. Following the literature review presented in the next two sections, the main arguments and research questions raised in this paper are presented in section 4. In section 4 I will draw on the pre-print debate[1], for an earlier version of this paper, that took place in the fourth quarter of 2001. This will enable me to lay out the main arguments and questions raised in this paper. Consequently, section 4 refers to reviews and commentaries that occurred in the online debate and the responses by myself. Given that the main concern of this paper is dialogue, and that the JiME review process encourages exploratory dialogue, it is felt that such an inclusion is appropriate. Indeed, this online review process is an excellent example of how we use language to think together (Mercer, 2000) and to clarify what it is that is being discussed. Section 5 presents the evolutionary approach, which focuses in on the relationships between the three points in what I am calling an evolutionary approach to new educational media theorising: (i) theories/models of learning, teaching and interaction (ii) empirical observations of learning, and (iii) interactive learning environment design and implementation. The evolutionary approach involves a constant process which slowly takes the field forward in iterative steps. My perspective is that no big bang or revolution is imminent with respect to theorising and modelling. Instead, I advocate cycles around the three points of evolution; this will, I suggest, bring about the gradual development of the field of learning technology, allowing us to adapt theories and models to suit our own perspectives.

## 2 How and why does one learn from dialogue?

Dialogue between teachers and students may be important in promoting learning (e.g. Vygotsky, 1978; Leontiev, 1975; Elsom-Cook, 1990; Lipman, 1991; Jones and Mercer, 1993; Freire, 1993; Baker, 1994; Cook, 1994; Pilkington and Mallen, 1996; Cook, 1998; Mercer, 2000; Ravenscroft and Matheson, 2002). This section attempts to examine the question: how and why does one learn from dialogue?

Students who are placed in a learning environment will usually need to interact with a teacher or learning facilitator at some point, in order to receive guidance (Elsom-Cook, 1990), feedback

1 *http://www-jime.open.ac.uk/Reviews/get/cook/1.html?embed=-1*

and explanations. The adaptive role of a teacher is of central importance to learning (Laurillard, 1993) because learning resources and media, such as books, journals, CD-ROMS, online databases or World Wide Web resources, etc., are rarely able to adapt to a particular group or individual's learning requirement. Students bring different histories of learning with them to a particular situation and therefore have different learning needs (Laurillard, 1993; Ramsden, 1992). Furthermore, these resources and media, typically, do not provide guidance on how they should be integrated and embedded in a coherent fashion so that learning can occur. For example, the tutor may be required to mediate between the learner and their understanding of the way in which they should use learning resources in order to meet the assessed learning outcomes of a particular programme of study. Consequently, in a learning environment, we get a complex set of relationships between how a learner thinks, i.e. cognition, how the learner interacts with teachers and peers, and the various media and resources that are available to support learning. The institution and society in which the learning takes place will also exert an influence on learning in more subtle ways.

The teacher is often more than a source of information. As was pointed out above, the teacher plays a key role in mediating a student's learning, acting as a kind of go-between or guide for the learner as they engage with the various elements of the learning environment, i.e. as they engage with other learners and tutors, learning resources and media, programme learning outcomes and assessment methods (Knight, 1995). The teacher can also help the learner to become more autonomous, to learn how to learn, and to reflect on his or her own problem-solving. The way that such explanation and guidance is provided by a teacher is usually through dialogue, either face-to-face, written or virtual, since this enables the teacher's help to be adapted and individualised to a particular student's needs. Dialogue also enables the student to verbalise and articulate his or her needs and understanding. This latter process of making knowledge explicit, and reflecting on it may itself be an interactive learning mechanism (e.g. Chi, Bassok, Lewis, Reimann and Glaser, 1989). Providing computer-based learning support that is able to acquire aspects of the role of 'teacher as mediator' is a growing area of research and development. Indeed, we are now starting to build up a rich picture of 'how' we learn from dialogue. However, in this paper what I am claiming is that, although there are many references in the literature on interactive learning mechanisms as they relate to computer-based learning (e.g. van Joolingan and de Jong, 1991; Baker, 1994; Baker and Bielaczyc, 1995), we still do not have sufficient detailed knowledge concerning the relationships between theory, empirical work and implementation of learning environments.

In contrast to the teacher as mediator perspective, Constructivism (described by Wasson, 1996) sees the major goal of education as the creation of rich sets of cognitive tools to help learners explore and interact with their environment and is closely associated with Piaget's (1971) genetic epistemology theory of cognitive development. Papert's (1980) Turtle Logo is a classic example of a learning environment that attempts to embody cognitively relevant tools in the environment. In the case of Logo, the cognitive tools, or cognitive hooks as Papert called them, are claimed to be the graphical immediacy of geometry drawn in real-time. These cognitive hooks are intended for the young learner to use as a tool to enhance the motor skills which they have acquired from birth. Cognitive tools are generalisable tools used to engage learners in meaningful cognitive processing, knowledge construction and facilitation. For example, computer-based cognitive tools are in effect cognitive amplification tools that are part of the environment. Environments that employ cognitive tools are described as distributing cognition; they are constructivist because they actively engage learners in the creation of knowledge that reflects their comprehension and conception of the information rather than focusing on the presentation or transmission of objective knowledge. It is this last item that contrasts with the behavioural approach (see, Hartley, 1998, for a description) which would focus on content selection, sequencing, structuring and presentation.

Taking a different perspective, Jones and Mercer (1993) have argued that a theory of learning, e.g. Behaviourism or Constructivism, is not the best framework for analysing what goes on in understanding the use of media like computers in education, rather a theory and analysis of teaching-and-learning is needed. The evolutionary framework, described in this paper, takes a similar approach, drawing as it does on theory and analysis of teaching and learning. Jones and Mercer are in favour of approaches to understanding teaching and learning that have been based on Vygotsky's cultural-historical theory of human activity. For Vygotsky (1978), human mental functions appear first as inter-individual and then intra-individual, that is, by the use of socially developed tools, both technological and psychological ones. However, surprisingly little evidence has been offered to support these claims (Mercer, 2000, p. 155). For Vygotsky the unit of analysis was still the mediated action of an individual and how that individual developed. Leontiev (1975) expanded Vygotsky's cultural-historical theory to an activity theory approach to human interaction where reality consists of mediated, social, hierarchically organised, developing, internal and external, object-oriented activities. For Leontiev the unit of analysis was extended to include the collective activity, something done by the community with a motive (which need not be consciously recognised), which is composed of individual actions directed towards a goal. The individual's mediated actions could still be analysed, but there was now a social dimension which could be used to understand the individual's actions.

Recent work with computer-based simulations (Twigger, Byard, Draper, Driver, Hartley, Hennessy, Mallen, Mohammed, O'Malley, O'Shea and Scanlon, 1991; van Joolingan and de Jong, 1991), which are used to help students acquire explanatory accounts of the real world, shows that students may fail to generate deep causal models of the behaviour under simulation because they concentrate on manipulating the simulation objects. With respect to the previously stated finding, Pilkington and Mallen (1996) make a strong case for a more Vygotskian (1978) perspective in interaction, i.e. where the teacher mediates knowledge about the society and culture so that it can be internalised by the learner. Interestingly, this raises the following question: is this knowledge already formed and finding its way into the learner? If so, this would suggest a knowledge transmission model of education. In fact I do not mean to suggest this interpretation. In my interpretation, interaction is seen as an important component of the learning environment, helping students to recognise and resolve inconsistency, i.e. it has an adaptive mediating role. Furthermore, Pilkington and Mallen have also point out that:

*…if we are to improve the quality of the interaction, then we need to understand the mechanisms by which dialogues work ... We need to know how and why, some kinds of dialogue … seem able to trigger reflective engagement and conceptual change. (Pilkington and Mallen, 1996, p. 213–214).*

Recently, some researchers have suggested that dialogue with a teacher may be required if the goal is to promote reflection and conceptual change:

*… self-reflection, or even reflective discussion between students may not be effective in changing beliefs and their 'organisation' into conception. This requires dialogue with a teacher. But … can a computer system be improved/designed to assist the reflective process, and if so, what are the requirements of its improvements? (Hartley and Ravenscroft, 1993, p. 3).*

The above researchers (Hartley and Ravenscroft, 1993) go on to describe a system called SCILAB, which was designed to explore one approach, for the domain of science, to providing dialogue that encourages reflection.

Lipman (1991) has proposed an approach to learning through dialogue and has suggested that we must stipulate that education should include reasoning and judgement about knowledge. Education in the Lipman sense of the word is not 'simply' learning, it is a Vygotskian-like teacher-guided community of inquiry that places an emphasis on social interaction and cooperative learning. Lipman calls this the reflective model of education practice. In a community of inquiry, the teacher becomes a facilitator and the student can take a shared, active and reflective role in the development of their own understanding (Mercer, 2000, p. 161). As we will see in subsequent sections, Lipman's work has been influential on the author's own work in the area of promoting learning through dialogue.

Mercer (2000) extends the work of Vygotsky and introduces the term 'interthinking' "in order to focus attention on the joint, co-ordinated intellectual activity which people regularly accomplish using language" (Mercer, 2000, p. 16). Mercer suggests a breaking down dialogue in the following way: disputational, cumulative, and exploratory, and begins to suggest the useful features of each to learners. Indeed, Mercer has started to address the difficult question posed at the start of this section: how and why does one learn from dialogue? Mercer talks about ways dialogue can fail as well as be successful, which seems critical to furthering our understanding of the area. For example, Mercer (2000, p. 145) points out that observational research in the classroom on children's activities in pairs and groups is 'unproductive', with more 'disputational' than the desired 'exploratory' talk happening. Mercer also reports success with interventions using his 'Talk Lessons': "children who have done the programme discuss issues in more depth and for longer … [and can] think together critically and constructively" (Mercer, 2000, p. 151).

A listening approach to the use of dialogues has been put forward in the Vicarious Learning project (e.g. see McKendree, Stenning, Mayes, Lee and Cox, 1998). This work attempts to suggest what dialogue contributes to learning that may be quite difficult to achieve in other ways. Specifically, the project was interested in exploring the benefits to learners of being able to observe others participating in dialogues. There is, however, evidence both for and against the effect of overhearing dialogues on learning (see McKendree, Good and Lee, in press). For example, Schober and Clark (1989) suggests that participants in their study who engaged in conversations with a "Director" performed better than overhearers. McKendree et al. (in press), however, counter that Schober and Clark were matching ambiguous figures in the study. What these differing results may point to is, perhaps, the suggestion that key factors in dialogue in learning are (i) the type and purpose of the dialogue (ii) the type of performance that is being measured, and (iii) the stance of the person being measured: an overhearer that takes an active stance might do just as well in a conversation, a learner that is not as active, and hence does not engage, probably would not do as well in either the overhearing or conversational modes (McKendree, J., personal communication, 30th November, 2001). What does seem certain is that the issue of exactly 'how' dialogue promotes learning is a complex one. Indeed, Mercer (2000, p. 173) admits that his "models of talk [disputational, cumulative and exploratory] are simplifications of complex reality which will need to be refined, or even replaced, as we learn more about the nature of interthinking".

To be truly equal and transformative, dialogue should not just be about content or about making appropriate use of a learning environment; it has to extend to the choice of what is to be learned, decisions about how it is to be learned and even institutional questions (Moore and Kearsley, 1996). This relates to the way that some distance learning writers talk about transactional distance: the perceived degree of separation during interaction between and among students and teachers. Moore and Kearsley (1996) describe transactional distance as having two components: dialogue and structure. Dialogue in this context refers to communication between students and their teacher and structure refers to the "responsiveness" of the educational plan to the individual student. One interpretation of the term 'educational plan' could be an orchestrated learning environment, e.g. a module that draws upon problem-based learning or an institution that is based on a particular educational school of thought. The educational plan can thus include theory and models of learning and interaction.

Work is currently being done with applications of the Russian literary theorist Bakhtin's (1981) model of dialogic discourse to Computer Mediated Communication (e.g. Galin and Latchaw, 1998). While not really concerned with design, these early attempts at introducing Bakhtinian theory into the analysis of the uses of educational technology elucidate the concept of dialogue and see it as a broad and complex activity (as was pointed out above), which is inscribed by struggles of power and authority. However, the concept of 'control' may be more useful than that of 'power' (Mercer, 2000, p. 95) in the context of using dialogue to promote learning. Someone in a position of power may still not retain control of a situation; instead we should judge the effectiveness of dialogue for exerting control in context.

To conclude this section, I suggest that we are starting to build up a rich understanding of 'how' dialogue promotes learning, but that more work is needed to understand 'why' it promotes learning. In this section we have seen that it would appear that certain types of learning may not occur unless dialogue takes place between a tutor and learner(s). Interaction has an adaptive mediating role, helping students to recognise and resolve inconsistency. Furthermore, dialogue may take various forms: disputational, cumulative, and exploratory; but that exploratory dialogue may be more likely to lead to in-depth learning. In addition, overhearing the dialogues of other may have a positive impact on learning. To be truly equal and transformative, dialogue has to be responsive to institutional questions and educational plans. However, in order to improve our understanding of interactive learning mechanisms (i.e. 'why' dialogue causes learning) in the context of the use of new media like computers, I suggest that there is a need to link theory to the analysis of teaching-and-learning interactions.

## 3 System design based on studies of human communicative interaction

In this section the following question is examined: how, or to what extent, can theories and studies of dialogue and interaction be exploited in a concrete way by designers of interactive media for education? In computer-based learning there is very little work that is based on dialogue analysis. The work that has been done tends to examine students' interactions with existing computer-based systems (e.g. Pask, 1976; Recker, 1994; Pilkington and Parker-Jones, 1996), although Anderson (e.g. Anderson and Boyle, 1985) has spent many years modelling the cognitive competencies that are taught in the domains of mathematics, computer programming, and cognitive psychology. Furthermore, Laurillard (1993, p. 102) has proposed a template for conversations that aims to map out, at a very high level of abstraction, the steps that are required for the design of interactive and adaptive media. However, Hartley (1998) has pointed out that although the applications of technology in education are becoming more numerous, they tend to be "disparate, pragmatically oriented, and largely descriptive in the accounts they present" (Hartley, 1998, p. 20), and that we still need systematic development frameworks that are able to "link theories to methodologies and practice" (Hartley, 1998, p. 36).

The idea that we can somehow base system design on a study of dialogues is a separate concern to building systems that promote dialogue, although the former may lead to the latter. The analysis of communicative interactions may lead to important insights that guide interactive media development on a philosophical and theoretical level. Alternatively, the results may be used to suggest useful tutoring strategies that can be used in a particular learning situation. However, educational research on interactions has tended to focus on a level of analysis and description that is of limited value for the types of models and theories that we wish to construct and use as the basis of learning environment design. This level of description claim does not suppose that educational research is, or has been, carried out at the wrong level of detail. Rather, the claim is that the gap between the level at which educational research is conducted and the fine-grained detail required for learning technology approaches has, up to the present, been too great to be bridged. Support for this claim can be found in the literature:

*... most of this work [educational research on interactions] is descriptive and statistical in nature. It tells us that a teacher spends 40% of his or her time responding to student-initiated activity (or whatever) but offers no help in understanding the processes and mechanisms involved. Similarly, the non-quantitative work, based on sociological and anthropological approaches, is of limited value for the types of models and theories which we wish to construct in AI and Education ... we must obviously look at education if we are to find out about educationally specific goals. It is not clear, however, whether we can derive the information we need from existing work. There is a large gap to be bridged in terms of levels of description. If the gap cannot be bridged, then it is necessary for AI and Education to include repetitions of previous research at finer levels of detail. (Elsom-Cook, 1991, p. 76–77)*

Over a quarter of a century ago the designers of the WHY system attempted to formalise the Socratic method for tutoring about the rainfall processes on the basis of a study of human tutoring (Stevens, Collins and Goldin, 1982). Anderson's tutoring research (e.g. Anderson and Boyle, 1985) has been advocating and writing about the importance of looking at what students do and what tutors say as a corpus for designing teaching systems for 20 years.

More recently, the AutoTutor system has been designed to assist college students on a computer literacy course (Graesser, Wiemer-Hastings, Wiemer-Hastings, Kreuz & the Tutoring Research Group, 1999). AutoTutor uses an analysis of human tutors as the basis for its dialogue moves and discourse patterns in a curriculum script. The AutoTutor researchers attempt to use speech act theory (Austin, 1962; Searle, 1969) as the basis for their system's dialogue planning. Also, this is the approach of the CIRCLE project in the USA, which is explicitly aimed at the goal of building dialogical learning systems, see http://www.pitt.edu/~circle/. MetaMuse (Cook, 2001) is a system that attempts to promote a Lipman-like community of inquiry (Lipman, 1991) in the context of undergraduate musical composition. MetaMuse is based on a theoretical and dialogue analysis approach (Cook, 1998) that makes used of higher-level, goal-based interaction analysis and communicative act theory. Because all situations are not ideal for speech only interactions (e.g. music), in this work Cook (1998) specifically extends the notion of a communicative act to include other acts like music and gestures (e.g. pointing).

To conclude this section, I propose that further work is needed that explores the systematic relationships between theories and models, empirical work of a fine-grained nature and the implementation of learning environments. Although some work has been done in area, I further claim that there is a need for a clearer mapping out of the problem space, both in descriptive terms and from an analytical perspective. Such a mapping exercise should enable us to draw conclusions and take the field of learning technology forward. In the next section I investigate the research questions presented in this paper in the context of the evolutionary approach.

## 4 Main argument and research questions

In this section I present the main arguments and research questions raised in this paper. I will draw on the pre-print debate[2] for this paper that took place in the fourth quarter of 2001. So what is my argument and the questions that relate to it?

In this paper I argue for an evolutionary approach that provides a model by which research in learning, teaching and theories of interaction can jointly feed into the design process of learning technology. This model attempts to make explicit a systematic relationship between theoretical framework, analysis of empirical data and computational implementation. There are various aspects to this model, which are explored in the paper (section 5); for example, working towards design from theory or working from empirical observation to design and even working from design to theory. Below I list four research questions and then elaborate on how they fit into my argument structure.

**1st research question:** How and why does one learn from dialogue?

**2nd research question:** How, or to what extent, can studies of dialogue and interaction be exploited in a concrete way by designers of interactive media in education?

**3rd research question**: How do we design situations, intended to promote learning from dialogue, in a human-computer context?

2 *http://www-jime.open.ac.uk/Reviews/get/cook/1.html?embed=-1*

**4th research question:** How do the above 3 questions relate to each other?

In summary, I argue as follows:

**Point 1.** Although dialogue is important in promoting learning, especially when we take into account the recent interest in Internet-based Computer Mediated Communication (CMC), we do not have available to us the precise details of the mechanisms of interactive learning for all domains.

**Supporting evidence for point 1.** Essentially I am claiming that we do not have detailed answers to research question 1 in all of the various disciplines. Some excellent work is progressing in certain areas; e.g. see Section 2 of this paper.

**Point 2.** This problem (noted in point 1) also arises for the case of human-computer educational dialogues, yet here we have the added problem that we need to know how to design new interactive education media (e.g. pedagogical agents, CMC) that are capable of sustaining such dialogues. So there is an added question (research question 3): How do we design situations, intended to promote learning from dialogue, in a human-computer context?

**Point 3.** Two possible approaches to designing new education media are 'theory-intuition to design-evaluate-and-refine', and from 'human-teacher-student-dialogues and theory to design-evaluate-and-refine'. In my own work, I have chosen to focus on the second approach, because, given that many of disciplines have not yet been adequately formalised, our intuitions can not be sufficiently informed. It is therefore reasonable to begin from what human experts do, to modulate this knowledge to system design and refine the system on the basis of evaluation (in section 5 I partially addresses research question 2 and 3 for a limited part of musical learning).

**Counter argument[3] to point 3 by Reviewer 1 (Anon).** The first approach to design, mentioned above in point 3, is the most common. Indeed, Reviewer 1 points out that theories, which typically have little specific to say about process, seem at the moment to be distant from design. The typical approach being one of going for design based on intuition and experience, then running a trial and then refining techniques on the basis of evaluative feedback from the trials; there is, generally speaking, only a nod in the direction of theory and the problems of practice.

**Cook's response to the above counter argument by Reviewer1**. I accept that, in the cut and thrust of designing educational systems for practical use, theory is often overlooked or marginalised as excess baggage. For example, look at the recent techno-centered developments with reusable learning objects (IMS <http://www.imsproject.org/metadata/>, IEEE LOM <

3 *http://www-jime.open.ac.uk/Reviews/get/cook/1/1.html*

http://ltsc.ieee.org/wg12/>, etc.). However, what I propose is an approach to research in this area, which is really a sensible research framework in my view. Consequently, I present a simple model that attempts to make explicit a systematic relationship between theoretical framework, analysis of empirical data and computational implementation. The following question then arises: Why bother? There are two good answers to this question. Firstly, we can not assume that we know how to design systems that match to the cognitive capacities of users, or indeed that mesh smoothly with the social and organisational settings in which the system will be used. Many existing IT systems have not been successful because these factors have not been incorporated in their design (Landauer, 1995). More research is needed that attempts to systematically solve the previously mentioned problems, and that then feeds this knowledge back into the evaluation and design of more effective IT systems and products (Norman, 1986, 1996; Long, 1996). The second answer to the 'why bother?' question starts with a further question: what were the main research concerns in 1991? The Elsom-Cook quote (section 3) highlights the claim that, ten years ago, one (possibly specialised) view was that a lot of the work needed redoing for AI in Education purposes. The, implicit, idea being that once this fundamental work had been done, we could then speed up the production of educational systems by drawing on a stronger empirical and theoretical foundation (think of Van Lehn's work on the Andes system (e.g. Gertner and VanLehn, 2000) based around the self-explanation empirical work of Chi and team (e.g. Chi, Bassok, Lewis, Reimann and Glaser, 1989) and indeed by Van Lehn himself). Ten years on from the Elsom-Cook quote I would claim that this fine-grained work still needs to be conducted in some domains. (But perhaps not all? Have the problems been cracked in science and mathematics?).

**Point 4.** Further counter argument[4] by Reviewer 1: Can current observations help if the educational approach with the computer is innovative and is to disturb the (current) educational process? I take this to mean that once we have observed human tutors, which may in itself disturb what is being observed, and have used the findings to build a wonderful new system or to inform how we organise CMC, how valid are observations of this new computer-based approach when this novel approach is essentially disturbing the status quo, i.e. changing the previous pattern of educational practice; see also Draper and Anderson (1991) for a discussion on these issues.

**Cook's initial response:** This is an interesting point, here is a brief response. I have done some action research into introducing a Lipman-style community of inquiry (which entailed opportunities for vicarious learning) to multimedia undergraduates (see Boyle & Cook, 2001; Cook, Leathwood and Oriogun, 2002). The innovation was embedded into CMC work and assessed, and according to student ratings was a success for 2 years running. I personally viewed it a success but have not analysed the dialogues in any detail (although students were given marks for successfully conducting an argument, i.e. for content and context of their postings). I see

4 *http://www-jime.open.ac.uk/Reviews/get/cook/1/1.html*

such innovation as the life-blood of the reflective practitioner, but am aware of the sensitivity that has to be applied when introducing innovation. I recently described, in a talk (LTSN Information and Computer Science 2001 conference) my approach to facilitating a community of inquiry and vicarious learning (i.e. small group, online, assessed debates which were open for all to students to observe or even participate in; a form of peer learning). At the talk one colleague was very surprised that I allowed such openness, commenting that her students insisted on privacy for assessed group work. Lachlan MacKinnon (from Heriot-Watt, who was associated with some of the early vicarious learning work) was chairing the session and supported me by making it clear that, ideally, students should to be exposed to dialogues, they had to experience them in order for the vicarious learning effect to work. My further response was that my approach was based on a theory that has been used in practice. Lipman's (1991) approach is used world-wide to teach philosophy to children, I have used it with a music educator in the domain of music composition education (Morgan and Cook, in press) and the students involved in the second year of multimedia module innovation gave the online critical debate a 70% satisfaction rating (Cook, Leathwood and Oriogun, 2002).

The point is that the introduction of new interactive media in education can create more problems than it solves. However, if handled with care (e.g. as action research) then it can provide new opportunities. In the second year of my innovation, I introduced online critical debate to 123 students from a wide variety of educational backgrounds. I feel strongly that this is something that I could not have achieved so effectively by conventional means and the limited resources that pervade the post-1992 universities in the UK. Going back to the evolutionary approach, I started from theory and went to design of a CMC environment, action research on the practice revealed success and problems which fed back into resigns of the CMC approach.

**Point 5.** Regarding research question 4, how do research questions 1 2 and 3 relate to one another? I hope the above discussion has shed light on this question. My own view is that we need to examine all three questions in a systematic way. These questions should be examined in the context of the three aspects of the evolutionary approach: theory, empirical work (or indeed other research methods) and computational implementation; and hence made the object of deep intellectual debate. In the next section I provide a detailed account of the evolutionary approach and illustrate it with examples from three researchers.

## 5 Evolutionary approach to theory

In this section I present an evolutionary approach to analysing the role of theory/models, empirical work and technology in learning. Specifically, the purpose of this evolutionary approach is the mapping out of not a specific theory, but a mapping out of how different researchers are working towards the creation of theories. As Mercer (2000, p. 73) points out:

*The creation of human knowledge is not simply the accumulation of facts, skills and ways of making sense of experience. It is also a process of evolution, in which alternative explanations, proposals and solutions compete for survival.*

The point being that in the evolutionary approach there is a requirement to be transparent about the theory and models in use. This requirement, in itself, may not communicate well from one discipline to another, as words have difference meanings in different disciplines; indeed, words have different meanings within a discipline. The only solution to this problem is, in my view, careful and continuing dialogue between all stakeholders. The evolutionary approach contains the following three components:

1. **Theories/models of learning, teaching and interaction**. A theory or model can be used as a means for understanding and predicting some aspect of an educational situation. Theories are not the same as models. A theory can posses an explanatory power and can consist of a set of

*general assumptions and laws … that are not themselves intended to be directly (in)validated (for that, the theory must engender a model). Theories are foundational elements of paradigms, along with shared problems and methods (Kuhn, 1962)*
(Baker, 2000).

Thus, a theory of cooperative problem-solving should predict what forms of cooperation should exist, and ideally what interactive learning processes they trigger. A model of an educational process, with its attendant theory, can be used to form the basis for the design of a computer tool for education (Baker, 2000). What is meant by a 'theory' or 'model' can vary across the different disciplines. For example, they may manifest themselves as descriptive, explanatory, analytical, quantitative, symbolic, analogue, or other approaches. I will leave it to others in this Special Issue of JiME to debate these issues.

**2. Empirical observations of learning.** This may involve a variety of research methods used to observe human-human interactions or human-computer-based learning environment interactions (some researchers may observe computer-computer dialogues). For example, the phenomenon predicted by a model of cooperative problem-solving may be tested by quasi-experimental method. On the other hand, other research approaches, e.g. grounded theory, may come in at this point from the perspective of immersion and experience of the educational interactions, deferring theorising until data is analysed (theorising may be deferred indefinitely in some cases).

**3. Interactive learning environment design and implementations.** This is the building of a computer-based educational artefact. An example of a model-based approach being linked to the artefact is provided by Baker and Lund (1997), who describe a model of task-oriented dialogue that forms the basis of design and implementation of tools for computer-mediated communication between learners and teachers in a computer-supported collaborative learning environment.

If we accept Baker's (2000) argument that models are not, by their nature, necessarily computational models of individual cognition, this opens up a wide range of possible ways in which theories and models can form the bases of design of educational artefacts. As Baker (2000) also points out, what is required of such an endeavour is that the specific nature of the relations between theory, model, corpus (i.e. transcriptions of interaction data), and design of learning environments be made as explicit as possible as legitimate objects of scientific discussion and as means of generalising findings towards re-design. The author's previous work (Cook, 1998; Cook, 2001) describes precisely such a principled relation for the case of a pedagogical agent for learning musical composition. This previous work by the author, which is summarised in Figure 1, explored the systematic relationships involved when moving from theory, i.e. the Knowledge Mentoring framework at the top of Figure 1, to an analysis of corpus data (Cook, 1998).

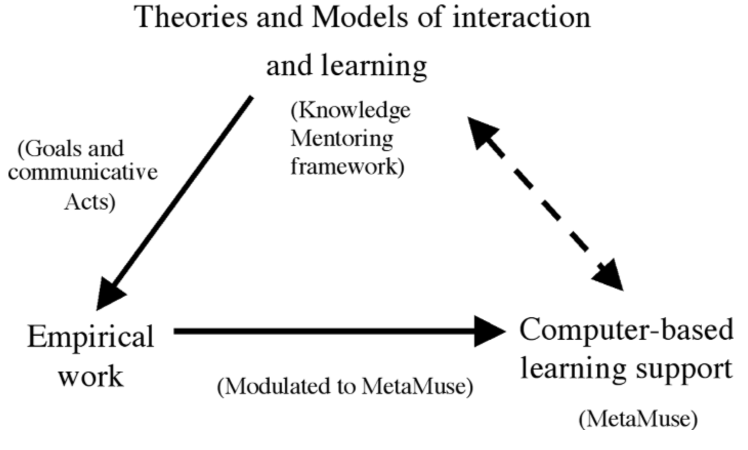


*Figure 1: Cook going anti-clockwise around the evolutionary approach*

Briefly, the Knowledge Mentoring framework is a theoretical framework of mentoring which includes the following sub-components: (i) categories of goals drawn from theory (Vygotsky and Lipman, who were described above), (ii) a three level analysis framework of goals, subgoals and communicative acts, (iii) a theoretical model of pedagogical agents (values, wants, commitment, intention and an action cycle). The categories and the three level framework were then used to guide the analysis of empirical data and to thus generate various results.

An analysis of corpus data (Cook, 1998), of human teacher-learner interactions, showed that in the domain of musical composition, creative problem-solving interactions (which I call problem-finding) had the underlying sub-goals *of probing, target, clarify and give reasons*. Specifically, the results of my empirical work indicated that the two most frequently used teaching interventions related to creative problem-finding were as follows. First was critical *probing*, where focused questions were used by a teacher, questions which were based on observations of a student's musical phrase; these questions had the intention of either helping the learner find an interesting problem to work on, or of prompting the learner to elaborate on their creative intention. Second was *target* monitoring or reflection level (in the learner); this was open-ended questioning that involved the teacher's attempts to elicit verbal self-explanations from the learner about their own attempts at specifying an interesting problem. Learner problem-finding involved 'critical *clarification*' (elaboration and refinement of some point may be requested or given because (i) a previous attempt was unclear or (ii) a response was required) and 'critical give *reasons*' (any interaction that involves the giving of criteria as a reason).

Figure 1 also shows that the empirical findings (Cook, 1998) were in turn used in the design of interactive system that is able promote learning through dialogue, i.e. MetaMuse in the bottom right of Figure 1. The dotted line in Figure 1 means that no explicit link exists between the two evolutionary points for the work under examination (but see below). Figure 2 gives an example of a MetaMuse interaction with a learner. The most recent dialogue output from MetaMuse is shown at the top of Figure 2 in the 'MetaMuse output' box.

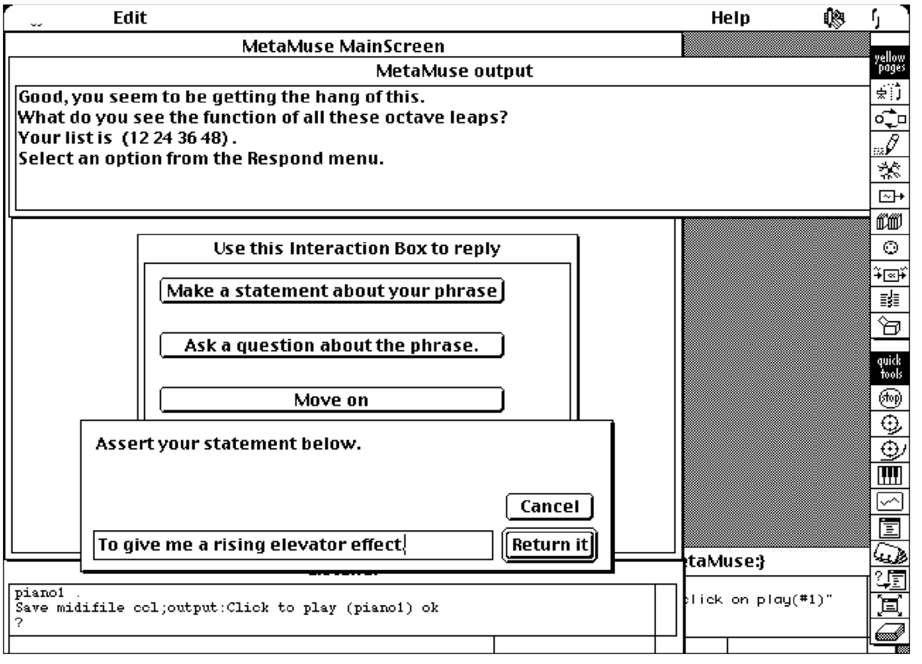


*Figure 2: Example of MetaMuse interaction with a learner*

The learner has already selected an option from the Respond menu, which is blanked out in Figure 2 because MetaMuse has now put up the Interaction Box in order to enable the learner to respond. The learner has selected the top button from the Interaction Box (shown in the middle of Figure 2): "Make a statement about your phrase", i.e. musical phrase, which leads MetaMuse to put up a dialogue box for the learner to enter an "assertion", which should provide clarification about what was intended with the octave leaps (the learner's list in the MetaMuse contains values that are all multiples of 12, and which are hence all octaves in the musical scheme used in MetaMuse).

I have argued (Cook, 2001) that the use of human expertise, when modulated, rather than transferred, to the computational medium, is an appropriate starting point for interactive media design; this argument is represented on the bottom line of Figure 1 (see also point 3 in section 4). By modulated I refer to the ability to pass from one state into another using a logical progression. In my own work the initial state was the corpus of data that resulted from the observation of human learning-teaching interactions. The target state was the incorporation of this data into a pedagogical agent design. A logical progression, i.e. the modulation, in my context involved the use of dialogue analysis and modelling techniques to enable aspects of interaction data to be converted into a computational model that was used in a learning support system. I was not attempting to transfer human expertise, which would involve attempts to computationally simulate, in a cognitive science sense, the human teacher. Instead, my goal was to modulate interaction data into the design of a computer-based pedagogical agent.

I now provide further explanation of the above argument. The issue of taking descriptive basis for system design, i.e. basing design on a study of dialogue and interaction, can be restated as the question: What is the nature of the argumentative link between the analysis-description of what a human teachers and learners did and the design of a system? The relation can not be one of direct transfer of expertise, for a number of reasons. On the purely dialogue side, you have open-ended spoken dialogue versus constrained human-computer dialogue. And then, artificial agents are not meant to be copies of human ones. The interaction analysis framework and the study described in Cook (1998, 2001) are part of a pedagogical agent design approach that aims to make practical use of empirical research in pedagogical agent development. I have argued, therefore, that because very few studies have examined how to develop an artificial agent in this way, i.e. to systematically link empirical data to agent design, the best starting point was to look at what human teachers and learners did, and to then implement descriptive models of that (in my case state transition networks). Refinements to the agent and to guiding theories or frameworks, e.g. the Knowledge Mentoring framework, can then take place on the basis of what happens in the real target dialogue environment when students use the system. Any refinement would thus take place as a result of formative evaluations.

Although the users in an initial evaluation of MetaMuse (Cook, 2000) reacted favourably, the initial evaluation of the pedagogical agent did not give much insight into the following question: what are the interactive means by which learning agents engage in cooperative, creative problem-solving? Consequently, I addressed this question by a detailed analysis of a transcribed corpus of the face-to-face interactions that took place between cooperating students when engaged with the pedagogical agent MetaMuse, i.e. I followed the link from empirical work up to theory (Figure 1). Specifically, the analysis results were used to clarify, at a fine level of granularity, a model of cooperative, creative learning. I proposed that, in cooperative dialogue, the interactions will not focus on 'winning the argument' or 'persuading your partner', it will involve an acceptance by both participants that they will attempt to 'find and refine' a problem specification; where a problem specification is a description of a problem that is interesting or novel. In this empirical work (Cook, 2000) interaction relating to cooperative, creative problem-solving was seen to revolve around a interactive learning process of find-predict-explain-refine; this process was achieved by the interacting learning agents (where an agent can be human or computer-based) primarily through the adoption of the goals 'probing, target, clarify and give reasons'.

Writing the redraft of this paper has prompted me to re-examine my corpus in order to address, from my perspective, the question 'how exactly does the process of find-predict-explain-refine work?' In fact I am trying to make the dotted line in Figure 1 solid (in that I am developing a theoretical model which I hope will give rise to a redesign of the computer-based agent). Cooperative-find-weak was observed in the corpus (Cook, 2000) and was defined as initial experimentation by the pairs in the study (who interacted with each other and MetaMuse). Cooperative-find is where the pairs were starting to come up with some novel idea; find-clarify was an elaboration of that creative intention. Below is an example from one of the sessions in which cooperative-find was identified; cooperative-find was identified on a total of 18 occasions in 6 sessions (indeed MetaMuse was designed to promote such interactions).

> 24: S: Right. Yeah. Would be [ADDS 4 TO LIST] one minor a third up from that original phrase, ah.
> 25: J: Right you got it.
> 26: S: Then it would be back [ADDS 0 TO LIST] again so I know what that's going to sound like because I'm a musician myself, but are you, do you know what it's going to sound like?
> 27: T: No not really, I have a rough idea but it's very rough I think. [PAUSE] Maybe I we can you can help me? [LAUGHTER FROM BOTH T AND S] See whether we hit or miss?
> 28: S: OK, well I'll put that what I'm going to do is [INSERTS A 1 AFTER FIRST 0]
> 29: T: Interesting.

The above extract shows the usual management of the interactions by the participants in order to facilitate cooperation; e.g. at turn 25 subject J confirms involvement in the dialogue presented in the previous turn by S. At turn 26 S takes on the role of a tutor with the adoption of a 'target' goal, i.e. the utterance "do you know what it's going to sound like?" is an attempt to elicit a verbal self-explanations from T about their joint attempts at specifying an interesting problem. At turn 27 T admits to having a "rough idea" of what the musical phrase that they are jointly composing will sound like. There is an imbalance in this dialogue in that S is taking the lead, but T seems happy to cooperate, explore, explain and learn. I would claim that MetaMuse has successfully structured the interactions between the two learners in order to set up the right conditions for a creative community of inquiry, where the learners take on the role of asking open-ended questions like the 'target' question at turn 26. Indeed, I would make the tentative claim that the reason 'why' this exploratory dialogue promotes problem-finding is because one of the participants has been encouraged by MetaMuse to take on the role of a tutor who asks open questions; i.e. *the type of questions that are asked is important*. An example of balanced problem-finding interactions, from the same corpus but from a different session, is shown below.

152: JA: But a test wasn't it, because up until this stage we've just being playing around to see what's been going on that's …
153: C: yeah if it was, if it was going to be creative the music doesn't sound unpleasant then, emphasise the first note of each phrase, possibly to make it more interesting.
154: JA: A reflection on how we would improve it from here or emm
155: C: It assumes it's creative in the first place I mean.
156: JA: Yes, so could improve, yeah move on or do you want to go back and play around with that one a bit more.
157: JA: [TYPES: "(EMPHASIS) COULD IMPROVE THE PHRASE"; CLICKS ON RETURN]

The cooperative problem-finding that occurs in the above dialogue extract is indicated by the fact that there is a tendency for each participant to finish off the other participant's sentence. The extract above shows the very first moment at which JA and C decide jointly to move on from the current attempt at creating a musical phrase, which JA at turn 152 describes as a "test" (i.e. cooperative-find-weak), and to now have a real attempt at creativity. JA's comment at turn 152 seems to prompt C to suggest that they might "emphasise the first note of each phrase" (turn 153) and that this would possibly make the phrase "more interesting". At turns 154 and 155 we get some joint 'find-clarification' on C's proposal in the context of the task they have been set. At turn 156 JA accepts this new direction and at turn 157 JA types in the creative intention into MetaMuse. In future work I intend to re-examine more of the corpus in order to pin down more precisely the exact mechanisms involved in the identified process of find-predict-explain-refine. Interestingly, tutors that encourage an open style of interactive dialogue, like that promoted by MetaMuse, have been found to be just as effective as when tutors give explanations and feedback (Chi, Siler, Jeong, Yamauchi, & Hausmann, 2001). One implication may be that pedagogical agents may not always need to have built within them a large knowledge-base, or indeed, complex user models. Instead, pedagogical agents, like MetaMuse, that structure interactions and promote an open style of questioning may be perfectly able to promote deep learning.

Baker has considered different issues with respect to the evolutionary approach. His relevant work is summarised in Figure 3. Unlike Cook, Baker (2000) argues that there should not be any modulation in the case of Computer Supported Collaborative Learning; rather, a corpus is a means of validating a model or theory of interaction and learning (i.e. theories of argumentation). Baker does not attempt to move from empirical work and modulate the findings into the design of a system (this is shown by the dotted line at the bottom of Figure 3). Instead, for Baker the problem is then shifted to that of understanding how exactly (quasi-)formal models of interaction and theories of cooperative learning can 'give rise to' computer-based learning support. That is to say, Baker starts with theories and models, has then run sessions to validate or disprove the model or theory, and has then used the revised theory or model to influence the implementation of computer-based learning support (the 'gives rise to' link in Figure 3). In fact the dotted lines in the descriptive diagrams, Figures 1 and 3, provide a limited analytical facility, in that we can see what aspect of the evolutionary approach is being omitted by a researcher This can in turn highlight areas for future work.

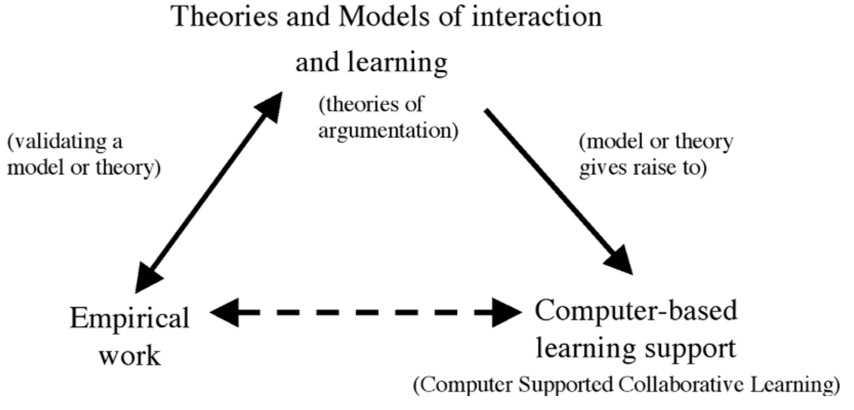


*Figure 3: Baker's focus in the context of the evolutionary approach*

Ravenscroft and Pilkington (2000) have used the evolutionary approach, shown in Figure 4, to develop a collaborative, computer-based framework for argumentation that addresses problems of conceptual change in science (Twigger et al., 1991), which was described above. The interaction was designed as a prescriptive 'dialogue game' (e.g. Levin and Moore, 1997) which modelled features of a tutorial process. Within the developed scheme the learner adopts the role of an explainer whilst the system plays a facilitating role, and these participants collaborate to develop a shared explanatory model of a qualitative, causal domain. A prototype system CoLLeGE (Computer based Lab for Language Games in Education) implements this theoretical framework and currently operates as a dialogue modelling 'workbench' for demonstrating, investigating and developing the approach. Furthermore, an empirical study was conducted which showed that performing this dialogue game supported the dialogue process in ways which stimulated students to revise and refine their beliefs, leading to conceptual change and development in science (Hartley and Ravenscroft, 1999). The empirical work was reused to improve the redesign of the workbench (the bottom line in Figure 4).

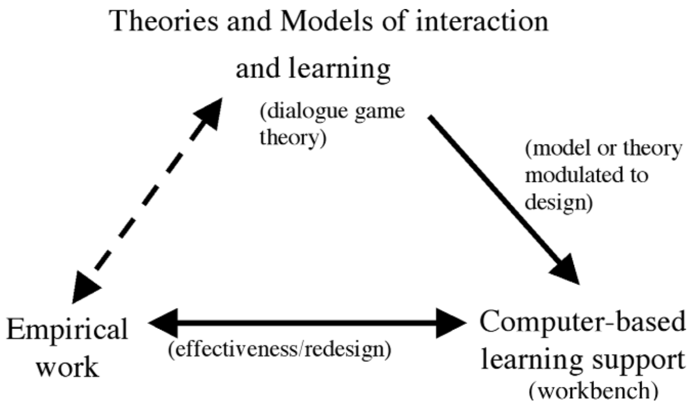


*Figure 4: Ravenscroft's focus in the context of the evolutionary approach*

The above examples have shown how the evolutionary approach is essentially one of iterative design in slow motion. The researchers described in this section have started from theory and models and proceeded to test them out by going either way around the evolutionary cycle. Not all researchers have completed a full cycle, but they may do so in the future. The following questions now arise:

- Are the approaches presented above complementary, or do they reflect inherently different value systems or approaches?
- Can one approach be used to extend the other? For example, do the gaps in the options that were highlighted above illustrate or warrant further investigation?

With respect to the first question, I would claim that very little work has been done on how to modulate data form studies to computer-based learning environment design. This is a contentious claim and I accept that there have been some notable exceptions (see section 3). Furthermore, although it is primarily a descriptive model, the evolutionary approach can help to explain the contributions of different studies and illustrate what further work needs to be done. Consequently, I suggest that it is possible to use my model – particularly the idea of gaps – to shape future work. For example, the author has, more recently, investigated educational dialogues form the opposite direction to Baker. In this recent work (Cook, 2000 – also discussed above) I describe how MetaMuse was designed to 'structure interactions' in such a way that would, it was predicted, facilitate creative problem-solving dialogues, i.e. I was starting from the bottom rights of the evolutionary model. I then used MetaMuse to generate interaction data (the gap in Baker's work). Thus, in this recent work I have travelled clock-wise around the evolutionary framework. The computer-based agent, MetaMuse, gave rise to dialogues in an empirical study, which when analysed gave raise to a fine-grained model of interaction and cooperative learning (Cook, 2000). This model may contribute to future theorising in the area of communities of cooperative, creative learning. Indeed, earlier in this section I took the first step in this direction by re-examining the Cook (2000) corpus in an attempt to build up a descriptive, theoretical model of the find-predict-explain-refine interactive learning mechanism. Once I have fully articulated this model, I hope to incorporate it into a redesign of MetaMuse (thus making the dotted line in Figure 1 solid).

In this section I have illustrated that the evolutionary framework can be helpful in identifying the theoretical work, and attendant dialogue analysis approach, that is being undertaken in the area of interactive media for education development. Furthermore, the evolutionary approach appears to have a high level of descriptive generality due to its simplicity and some potential as an analytical tool.

## 6 Conclusions

In this paper I have examined the role of dialogue in computer-based learning and observing learning. I have proposed that in order to improve our understanding of learning in the context of the use of new media in education, we need to link theory and models to the analysis of teaching-and-learning. Furthermore, I have posited that certain types of learning may not occur unless dialogue takes place between a tutor and learner(s). Interaction has an adaptive mediating role, helping students to recognise and resolve inconsistency. Explaining ones problem-solving strategy or overhearing the dialogues of others may have a positive impact on learning. Furthermore, dialogue may take various forms: disputational, cumulative, and exploratory; however, exploratory dialogue may be more likely to lead to in-depth learning. Indeed, in the previous section I have made the tentative claim that the reason 'why' some exploratory dialogues may promote cooperative learning is because one of the participants has been prepared to take on the role of a tutor who asks open questions; i.e. the type of questions that are asked is important. Finally, in this paper I have presented a three-part evolutionary approach to investigating theories and models of interaction and learning.

First, let me concede that in this paper I have not been able to provide conclusive answers to some of the research questions posed in section 4 (the themes are, as Reviewer 1 points out, big ones). Indeed, it was never my intention to do this. Let me explain my position by drawing a parallel with a position highlighted in a recent journal editorial piece called 'Introduction to this Special Issue on New Agendas for Human-Computer Interaction'. In this Kellogg, Lewis and Polson (2000) highlight some concerns in their field. Specifically, Kellogg et al. draw attention to researchers in the field who are *strongly critical of prevailing research practice in HCI … [that places a] disproportionate emphasis on radical innovation rather than evolutionary improvement in the field.*

In a similar vein to the above critique of Human-Computer Interaction, I am suggesting that attempts to provide a 'big' or unified theory to underpin learning technology development may be premature (even if they are valuable additions to the debate). Furthermore, I would argue that the overemphasis on technical solutions like those pervading the field of reusable learning objects must be replaced by hard work on a deep intellectual agenda. In this paper I have tried to draw on my own work for the past 10 years to propose a evolutionary approach that challenges new learning media researchers to think systematically about the very complex business of placing theories and models of learning, teaching and interaction at the centre of their activities. If I succeed in provoking thought and reaction, as I appear to have from the reviewers of this paper, then I will feel that the proposal takes us one step further on our "field's" evolution.

I conclude by suggesting that the evolutionary approach can 'potentially' help designers of, and researchers into, learning technology in three important ways (but accept that a lot more work is needed to justify this claim). First, it allows them to examine and compare the theories and models that are available for the design or research task in hand. For example, in the previous section I have demonstrated how the evolutionary approach can be used to compare different research projects. This should in turn enable a critical debate to take place, within the learning technology community, about what the different theoretical models and design approaches have to offer. Second, the evolutionary approach enables researchers and designers to develop models and theories that are appropriate to their own context, particularly in terms of educational objectives and the level of granularity. The use of interaction analysis is particularly useful in obtaining fine-grained data that can be used as the basis for the design of new forms of interactive media (i.e. modulated) or to verify a theory. Granularity is an issue for reuse of learning materials. For an approach to be valuable it is necessary for the learning objects themselves to be "identifiable, discoverable and useful at the smallest appropriate level of granularity" (MEG, 2001). A big problem with a lot of the current reusable objects research and development is that the theoretic basis from a pedagogical perspective is very rudimentary, with much of the development being on the technical level. The evolutionary approach could be used in helping to clarify the theoretical base for learning object reuse. Furthermore, if a fine-grained level of detail is not appropriate for a particular project then the evolutionary model can be used to zoom out, as it were, and take a higher level view of what is happening in terms of the three evolutionary points; for example, to examine the political and social aspects of learning. The third advantage of the evolutionary model is that it helps us to assess the ways in which different researchers are taking the area of learning technology theorising and modelling forward. In my view this last advantage is a key point that should lead to evolutionary, and not revolutionary, theorising in the evolving 'discipline' of learning technology.

## Acknowledgements

Thanks to Martin Oliver for making some useful comments on both the concept of the evolutionary approach and a draft of the paper. Thanks also to Alan Mclean for helpful comments on the literature review. Finally, thanks to all the reviewers (Roger Hartley, Colleen McKenna and Sarah Fletcher) and other researchers (especially Jean McKendree) who engaged in productive debate about the first draft of this paper.

## References

Anderson, J. and Boyle, C. F. (1985). The Geometry Tutor. In *Proceedings of 9th International Conference on Artificial Intelligence.* See < http://act.psy.cmu.edu/ACT/people/ja.html> for full listing of Anderson's research.

Austin, J. L. (1962). *How to Do Things with Words.* New York: Oxford University Press.

Baker, M. J. (2000). The Roles of Models in Artificial Intelligence and Education Research: A Prospective View. *International Journal of Artificial Intelligence in Education,* 11, 122–143. < http://www.cogs.susx.ac.uk/ijaied/>

Baker, M. (1994). A Model for Negotiation in Teaching-Learning Dialogues. *Journal of Artificial Intelligence in Education*, 5, (2), 199–254. < http://www.cogs.susx.ac.uk/ijaied/>

Baker, M. and Bielaczyc, K. (1995). Missed Opportunities for Learning in Collaborative Problem-Solving Interaction. In Greer, J. (Ed.) *Proceedings of the AI-ED 95–World Conference on Artificial Intelligence in Education* (pp. 210–217), held in Washington, DC, August 16-19. Association for the Advancement of Computing in Education.

Baker, M. J. and Lund, K. (1997). Promoting Reflective Interactions in a CSCL Environment. *Journal of Computer Assisted Learning,* 13, 175–193.

Bakhtin, M. (1981). *The Dialogic Imagination: Four Essays by M. M. Bakhtin.* Trans. Emerson, C. and Holquist, M. Ed. by Holquist, M. Austin: Universtity of Texas Press.

Boyle, T. and Cook, J. (2001). Online Interactivity: Best Practice Based on Two Case-Studies. *Association for Learning Technology Journal,* 9(1), 94-102.

Cook, J. (2001). Bridging the Gap Between Empirical Data on Open-Ended Tutorial Interactions and Computational Models. *International Journal of Artificial Intelligence in Education,* 12(1), 85–99 <http://www.cogs.susx.ac.uk/ijaied/>

Cook, J. (2000). Cooperative Problem-Seeking Dialogues in Learning. In G. Gauthier, C. Frasson and K. VanLehn (Eds.) *Intelligent Tutoring Systems: 5th International Conference, ITS 2000 Montréal, Canada, June 2000 Proceedings*, (pp. 615–624). Berlin Heidelberg New York: Springer–Verlag.

Cook, J. (1998). Mentoring, Metacognition and Music: Interaction Analyses and Implications for Intelligent Learning Environments. *International Journal of Artificial Intelligence in Education,* 9, 45–87. < http://www.cogs.susx.ac.uk/ijaied/>

Cook, J. (1994). Agent Reflection in an Intelligent Learning Environment Architecture for Musical Composition. In Smith, M., Smaill, A. and Wiggins, G. (Eds.), *Music Education: An Artificial Intelligence Approach, Edinburgh 1993* (pp. 3–23). London: Springer-Verlag.

Cook, J., Leathwood, C. and Oriogun, P. (2002). Online Conferencing with Multimedia Students: Monitoring Gender Participation and Promoting Critical Debate. *ITALICS* (eJournal: Innovations in Teaching And Learning in Information and Computer Sciences), 1(2). Paper online: http://www.ics.ltsn.ac.uk/pub/italics/issue2/cook/006.html

Chi, M. T. H., Bassok, M., Lewis, M., Reimann, P. and Glaser, R. (1989). Self-Explanation: How Students Study and Use Examples in Learning to Solve Problems. *Cognitive Science*, 13, 145–182.

Chi, M. T. H. Siler, S. A., Jeong, H. Yamauchi, T. & Hausmann, R. G. (2001). Learning from Human Tutoring. *Cognitive Science,* 25, 471–533. Paper can be downloaded from <www.pitt.edu/~Chi>

Draper, S. W. and Anderson, A. (1991). The Significance of Dialogue in Learning and Observing Learning. *Computers and Education,* 17(1), 93–107.

Elsom-Cook, M. (1990). Guided Discovery Tutoring. In Elsom-Cook, M. (Ed.) *Guided Discovery Tutoring for ICAI research* (pp. 3–23). London: Paul Chapman Publishing.

Elsom-Cook, M. (1991). Dialogue and Teaching Styles. In Goodyear, P. (Ed.) *Teaching Knowledge and Intelligent Tutoring* (pp. 61–83). Norwood, NJ: Ablex.

Freire , P. (1993). *Pedagogy of the Oppressed.* London: Penguin Books.

Galin, J. and Latchaw, J. (1998). *The Dialogic Classroom: Teachers Integrating Computer Technology, Pedagogy, and Research.* NCTE.

Gertner, A. S. and VanLehn, K. (2000). Andes: A Coached Problem Solving Environment for Physics. In G. Gauthier, C. Frasson and K. VanLehn (Eds.) *Intelligent Tutoring Systems: 5th International Conference, ITS 2000 Montréal, Canada, June 2000 Proceedings,* p. 133–142. Berlin Heidelberg New York: Springer-Verlag.

Graesser, A., Wiemer-Hastings, K., Wiemer-Hastings, P., Kreuz, R., & the Tutoring Research Group (1999). AutoTutor: A simulation of a Human Tutor. *Journal of Cognitive Systems Research,* 1, 35–51.

Hartley, J. R. (1998). New Technologies and Learning. In Shorrocks-Taylor, D. (Ed.), *Directions in Educational Psychology* (pp. 19–38). London: Whurr Publishers Ltd.

Hartley, J. R. and Ravenscroft, A. (1999). Supporting Exploratory and Expressive Learning: A Complementary Approach. *International Journal of Continuing Engineering Education and Lifelong Learning,* 9(3/4), 275–291.

Hartley, J. R. and Ravenscroft, A. (1993). Computer Aided Reflection: An Overview of SCILAB. *Paper presented at the SMILE Workshop, September 29th - October 1st,* Computer Based Learning Unit, University of Leeds, UK.

Jones, A. and Mercer, N. (1993). Theories of Learning and Information Technology. In Scrimshaw, P. (Ed.) *Language, Classroom and Computers* (pp. 11–26). London: Routledge.

Kellogg, W.A., Lewis, L. and Polson, P. (2000). Introduction to this Special Issue on New Agendas for Human-Computer Interaction. *Human-Computer Interaction,* 15(2/3), 1–4.

Knight, P. (1995) (Ed). *Assessment for Learning in Higher Education.* London: Kogan Page SEDA Series.

Kuhn, T. S. (1962). *The Structure of Scientific Revolutions.* International Encyclopedia of Unified Science, Volume 2, Number 2. London: University of Chicago Press.

Landauer, T. K. (1995). *The Trouble with Computers.* Cambridge, MA.: Academic Press.

Laurillard, D. (1993). *Rethinking University Teaching: A framework for the effective use of educational technology.* London: Routledge.

Leontiev, A. N. (1975). *Activity, Consciousness, Personality.* Moscow.

Levin, J. A. and Moore, J. A. (1977). Dialogue-Games: Metacommunication Structures for Natural Language Interactions. *Cognitive Science,* 1, (4), 395–420.

Lipman, M. (1991). *Thinking in Education.* New York: Cambridge University Press.

Long, J. (1996). Specifying relations between research and the design of human-computer interactions. *International Journal of Human-Computer Studies,* 44, 875-920.

McKendree, J., Good, J. and Lee, J. (in press). Effect of Dialogue Characteristics on Performance by Overhearers. Paper submitted to for review.

McKendree, J., Stenning, K., Mayes, T., Lee, J., and Cox, R. (1998). Why Observing a Dialogue May Benefit Learning. *Journal of Computer Assisted Learning*, 14( 2), 110–119. Other articles from the Vicar project can be found at <www.hcrc.ed.ac.uk/gal/vicar>

MEG (2001). The UK's Metadata for Education Group (MEG). *The MEG Concord.* Downloaded 9/3/01 <http://www.ukoln.ac.uk/metadata/education/documents/concord.html>

Mercer, N. (2000). *Words and Minds: How we Use Language to Think Together.* London: Routledge.

Moore, M. G. and Kearsley, G. (1996). *Distance Education: A Systems View.* Wadsworth.

Morgan, N. and Cook, J. (in press). Teaching Cycles in the Creative Community of Inquiry. *Musicus*, 6, to appear.

Norman, D.A. (1986). Cognitive Engineering. In Norman, D.A. and Draper, S.W. (Eds). *User Centred Design*. Hillsdale, NJ: Erlbaum.

Norman, D.A. (1996). Design as practised. In Winograd, T. (Ed.) *Bringing design to software.* MA: Addison-Wesley.

Papert, S. (1980). *Mindstorms.* Brighton: Harvester.

Pask, G. (1976). Conversational Techniques in the Study and the Practice of Education. *British Journal of Educational Psychology,* (46), 12–25.

Piaget, J. (1971). *Biology and Knowledge.* Edinburgh University Press.

Pilkington, R. and Mallen, C. (1996). Dialogue Games to Support Reasoning and Reflection in Diagnostic Tasks. In Brna, P., Paiva, A. and Self, J. (Eds.) *European Conference on Artificial Intelligence in Education (EuroAIED)* (pp. 213–219), held at Fundacao Caloustre Gulbenkian, Lisbon, Portugal, September 30–October 2, 1996. Edicoes Colibri.

Pilkington, R. and Parker-Jones, C. (1996). Interacting with Computer-Based Simulation: The Role of Dialogue. *Computers and Education,* 27, (1), 1–14.

Ramsden, P. (1992). *Learning to Teach in Higher Education.* London: Routledge.

Ravenscroft, A. and Pilkington, R.M. (2000). Investigation by Design: Developing Dialogue Models to Support Reasoning and Conceptual Change. *International Journal of Artificial Intelligence in Education*, Special Issue on Analysing Educational Dialogue Interaction: From Analysis to Models that Support Learning, 11, (1), 273–298. <http://www.cogs.susx.ac.uk/ijaied/>

Ravenscroft, A. and Matheson, M.P. (2002). Developing and Evaluating Dialogue Games for Collaborative E-Learning Interaction. *Journal of Computer Assisted Learning: Special Issue: Context, Collaboration, Computers and Learning,* 18 (1), 93–102.

Recker, M. M. (1994). A Methodology for Analyzing Students' Interactions within Educational Hypertext. In *Educational Multimedia and Hypermedia, 1994. Proceedings of EdMedia 94–World Conference on Educational Multimedia and Hypermedia* (pp. 474–479), held in Vancouver, British Columbia, Canada, June 25-30, 1994.

Schober, M. F. and Clark, H. H. (1989). Understanding by Addressees and Overhearers, *Cognitive Psychology,* 21, 211-232.

Searle, J. R. (1969). *Speech Acts, An Essay in the Philosophy of Language.* Cambridge: Cambridge University Press.

Stevens, A. L., Collins, A. and Goldin, S. E. (1982). Misconceptions in Students' Understanding. In Sleeman, D. H. and Brown, J. S. (Eds.), *Intelligent Tutoring Systems* (pp. 13–24). London: Academic Press.

Twigger, D., Byard, M., Draper, S., Driver, R., Hartley, J. R., Hennessy, S., Mallen, C., Mohammed, R., O'Malley, C., O'Shea, T. and Scanlon, E. (1991). The Conceptual Change in Science Project. *Journal of Computer Assisted Learning,* 7, 144–155.

van Joolingan, W. and de Jong, T. (1991). Supporting Hypothesis Generation by Learners Exploring an Interactive Computer Simulation. *Instructional Science,* 20, 389–404.

Vygotsky, L. S. (1978). Mind in Society. *The Development of Higher Psychological Processes.* Edited by Cole, M., John-Steiner, V., Scribner, S. and Souberman, E. Cambridge, Mass.: Harvard University Press.

Wasson, B. (1996). Instructional Planning and Contemporary Theories of Learning: Is this a Self-Contradiction? In Brna, P., Paiva, A. and Self, J. (Eds.), *European Conference on Artificial Intelligence in Education (EuroAIED)* (pp. 23–30), held at Fundacao Caloustre Gulbenkian, Lisbon, Portugal, September 30–October 2, 1996. Edicoes Colibri.