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Educational Technology: The Influence of Theory

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Abstract:

In this paper we explore the role of theories in current practice in educational technology. We review a range of writings from the past 30 years on the nature of learning technology research. We discuss influences on learning technologies from the related fields of Artificial Intelligence in Education (AIED) and Human-Computer Interaction (HCI). We identify two groups of theories which have been used. The first group are related to principled decisions about the design of learning materials. The second group influence the ways in which we frame our research on learning. Research in learning technologies in the future will need to draw on both groups of theories. In this paper, we draw on our own experiences as educational technologists and the purpose of the paper is to encourage other educational technologists to join with us in reflecting on their own use of theories.

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1 Introduction

The OU has had an Institute of Educational Technology (http://iet.open.ac.uk/) since its' inception, with the aim of carrying out research and supporting the use of technology in courses at the university. Increasingly, other universities are setting up similar departments with similar aims. The foundation of the Higher Education Research and Development Unit (now the Department of Education and Professional Development) at University College London in 1996 is an example of the current growth of interest in educational technology in traditional higher education institutions. Other examples include the Institute for Learning and Research Technology at Bristol University, and the Educational Technology Services at the University of Warwick. There has been a proliferation of groups and departments which to support effective teaching and learning within higher education, many with an emphasis on the use of technology and this had led to an enormous increase in the number of people engaged in the practice of educational technology. Therefore we consider it to be timely to examine how influences from the constituent disciplines have guided practice in educational technology. In particular we will look here at the idea of educational technology as applied educational science and how theories in these disciplines are used. We look here at influences from education, artificial intelligence in education and human computer interaction.

2 History of Educational Technology

Educational technology is a multidisciplinary activity that is currently enjoying a period of growth. The notion of educational technology as an applied educational science was given a great boost by the foundation of the Institute of Educational Technology in the early days of the development of the United Kingdom Open University in 1969. Its importance was recognised in the speech of the Open University's (OU) first chancellor Lord Crowther at the OU inaugaration on the 23 July 1969.

> *The world is caught in a communications revolution, the effects of which will go beyond those of the industrial revolution of two centuries ago. Then the great advance was the invention of machines to multiply the potency of men's muscles. Now the great new advance is the invention of machines to multiply the potency of men's minds. As the steam engine was to the first revolution, so the computer is to the second. It has been said that the addiction of the traditional university to the lecture room is a sign of its inability to adjust to the development of the printing press. That of course is unjust. But at least no such reproach will be levelled at the Open University in the communications revolution. Every new*

> *form of human communication will be examined to see how it can be used to raise and broaden the level of human understanding. There is no restriction on techniques.*

This extract is interesting as it accurately predicts the current concerns of educational technologists from the practical (techniques that work) to the importance of the communications revolution, the role of the computer, an examination of new media, and the consideration of the implications of communication for conventional as well as distance institutions of higher education.

According to Derek Rowntree (1979), one of the early OU innovators, educational technology is concerned with the design and evaluation of curricula and learning experiences and with the problems of implementing and renovating them.

O'Shea and Self in the early eighties pointed out that educational technology was no longer solely concerned with devices or equipment but was a branch of the behavioural sciences, which currently carries no commitment to any particular theory of learning. They continue:

> *Educational technologists would not therefore consider the computer as just another piece of equipment. If educational technology is concerned with thinking carefully about teaching and learning, then a computer has a contribution to make irrespective of its use as a means of implementation, for the design of computer based learning environments gives us a new perspective on the nature of teaching and learning and indeed on general educational objectives. O'Shea and Self (1983), p. 59*

In this paper we wish to explore how this new perspective might be developed. As practitioners of educational technology, our work involves the design, implementation and evaluation of examples of learning systems in higher education. Our work is in many ways entirely practical, requiring us to make decisions based on the potential of contemporary technologies. However, we find that the design and evaluation of teaching material, as O'Shea and Self point out, requires us to draw on research in a variety of disciplines, especially education. It also gives us the opportunity of designing experiments to test out designs based on theories and to help us explain the factors which influence the students' learning. Our aim as educational technologists is to improve the quality of students' learning.

It is interesting to note that some other commentators give theory less of a central role. For example, the 1996 Handbook of Educational Technology there is only one reference to theory in the index. Examining Etienne Wenger's (1987) influential review, the entry under theories says, see Bugs, Cognitive Knowledge communication, Knowledge Viewpoints. This is in sharp contrast to the ways in which we conventionally understand theory.

One of the most powerful images we have found to describe the activity engaged in by educational technologies is that put forward by Allan Collins (then at Bolt Beranek and Newman, Inc.) who sees educational technology as a design science, similar to the O'Shea and Self vision.

> *Technology provides us with powerful tools to try out different designs, so that instead of theories of education, we may begin to develop a science of education.*
>
> *But it cannot be an analytic science like physics or psychology; rather it must be a design science more like aeronautics or artificial intelligence. For example, in aeronautics the goal is to elucidate how different designs contribute to lift, drag manoeuvrability, etc. Similarly, a design science of education must determine how different designs of learning environments contribute to learning, cooperation, motivation, etc. Collins (1993), p. 24*

These commentators on educational technology have used ideas from a range of disciplines including education, computer science, artificial intelligence, systems design, psychology, physics, engineering, human computer interaction, sociology, linguistics and many more. In this paper, we provide an examination of two of these contributing disciplines: human computer interaction and artificial intelligence in education. We make no claims about the primacy of these disciplines, but they have been extensively applied in aspects of learning technologies where computers have been used as vehicles for teaching and learning.

3 Theories in AIED

Artificial Intelligence in Education (AIED) is a discipline which has had some impact on educational technology (although it is notable that this has been limited). The aim of AIED is to apply Artificial Intelligence in educational settings. AIED is essentially an engineering discipline, which involves theoretical and practical attempts to use computer systems to mimic human teachers and/or support learners. AIED, arguably, is dominated by the use of models to provide instantiations of theories which are then used for students' learning. Thus systems are designed to mimic the actions of human teachers.

However, although AIED was originally focused on the development of instantiated models of teaching, students, tasks etc, there has over the last ten years been a shift towards understanding how systems work in real settings. Brna, Ohlsson and Pain (1993) discuss the role of AIED:

> *The continuing pressure on educators to provide high quality solutions for effective teaching and learning will be a major force for change in the next decade. The field of Artificial Intelligence in Education has an important role to play. AIED provides, and will continue to provide, theoretical analyses of the processes of teaching and learning within a wide range of context. It will further develop evaluation methodologies that more accurately reflect the educational value associated with the experience of teaching and learning. It will also increasingly deliver computer-based systems which can be used in real teaching and learning situations. Brna, Ohlsson and Pain (1993), Preface.*

Baker (2000) argues that there are three uses of models of educational processes in Artificial Intelligence. These are: models as scientific tools, models as components of educational artefacts and models as the bases for design of educational artefacts. He claims that:

> *... a significant part of AIED research can be seen as the use of computers to model aspects of educational situations that themselves involve the use of computers as educational artefacts, some of which may incorporate computational models. Baker (2000), p. 123.*

In discussing the relationship between models and theories, Baker argues that an important purpose of a model is to enable elaboration or refinement of the theory on which it is based. He is not explicit about the role of theories, but appears to see theories as being modified and refined by models.

4 Theories in HCI

Traditionally, a key framework for HCI research has been information processing and cognitive psychology, with a focus on the task and the ways in which users perform tasks. HCI is a multidisciplinary field which aims to design systems which are used effectively and efficiently. As Nardi (1996) puts it:

> *A key aspect of HCI studies must be to understand things: technology-physical objects that mediate activity... Nardi (1999), p. 14*

However, more recently the fields has been influenced by a broader range of theories. A good example of this is the work of Hollan, Hutchins and Kirsh (2000) who argue that the theory of distributed cognition should form the basis of human-computer interaction research. They describe several theoretical principles which they claim distinguish distributed cognition from other theories of cognition. Firstly, that a cognitive unit of analysis is larger than the individual and cognitive processes occur "on the basis of functional relationships of elements that participate together in the process" wherever they may occur. Secondly, cognitive events do not necessarily occur within a human individual. Thirdly, one needs to study culture as well as cognition: "Distributed cognition returns culture, context and history to the picture of cognition." Hollan et. al. propose a new framework for the field of HCI, using an integrated research activity map. They identify a set of core principles which are used to scope the phenomena that HCI should address. They discuss how cognitive ethnography as a method should be combined with "ethnographically natural experiments." The relationship between the principles of distributed cognition, ethnography and experiments is crucial to the development of the field.

Rogers (2000) comments on the changes that have occurred recently in HCI:

> *From what was originally a scientific enterprise with limited scope and a specific set of objectives, where cognitive theory had its place (i.e. primarily to model human computer interactions), the field has now become much more eclectic, whereby theory is increasingly being imported, adapted and applied from a diverse range of disciplines besides cognitive psychology, such as anthropology, film studies and sociology.*

She discusses how HCI has moved beyond traditional cognitivism through a variety of mechanisms: abandoning theory in favour of empirical approaches, developing new terms for describing system design, importing alternative theories from different disciplines, turning to social disciplines to inform system design, evolving new fields and revising cognitive terrain. Rogers describes the range of "alternative psychological theories" including Activity Theory and Ecological Psychology. She discusses the "move to the social" – Situated Action and Ethnomethodology and the revisions made to existing frameworks including Distributed Cognition, External Cognition and the Interactivity Framework. She provides detailed descriptions, case studies and interpretations of these alternative approaches, with some assessment of their impact on HCI. Rogers argues that:

> *...one of the main contributions of continuing to import and develop new theories in HCI is to enable new concepts and rhetorical devices to be constructed that, in turn have the potential for developing a more extensive design language, that can be used both in research and design. Rogers (2000), p.20*

It is interesting to compare this perspective on the importance of design with the views of Collins (1992) on the difficulties of carrying out design experiments in educational technology:

> *Typically the experiments are carried out by the people who designed some technological innovation, so that they have a vested interest in seeing that it works. They typically look only for significant effects (which can be very small effects) and test only one design, rather than trying to compare the size of effects for different designs or innovations. Further more such experiments are so variable in their design and implementation that it is difficult to draw conclusions about the design process by comparing different experiments. Finally they are carried out without any underlying theory and so these results are for the most part uninterpretable with respect to constructing a design theory of technological innovation. Collins (1992), p. 24*

Collins sees the purpose of design experiments as a way to improve educational technology artefacts while Rogers is looking for the development of a design language with which to explain such experiments. It seems that there are a wide range of metaphors for design to draw on from engineering disciplines.

Mackay and Fayard (1997) make an interesting attempt to propose a framework that describes how the research and design models underlying HCI can be integrated. They make a fundamental distinction between the sciences and design and show how "HCI must necessarily draw from and benefit from both" (p. 223). They divide the contributing disciplines into natural and social sciences (psychology, sociology and anthropology) and engineering, design and fine arts (industrial design, typography and graphic design). The sciences operate within paradigms, while the engineering and design disciplines operate within schools (which dictate aesthetics and style). They discuss the different assumptions and values held by scientists and designers. They elaborate the deductive and inductive models used within science, in contrast to the design and engineering approach which involves moving from early prototypes to finished products using guidelines and rules of thumb, or principles from psychology. Their model makes an attempt to integrate scientific and design models but perhaps their most interesting contribution is that they advocate "cross disciplinary triangulation" which can increase the effectiveness of research.

It is unclear as yet whether these sorts of integrative approaches will bear fruit. This discussion of HCI shows how it is evolving to include interpretations and explanations of the culture and context which surrounds the use of systems. The goal of HCI has not changed, in that the aim is to design usable and effective systems, but researchers are recognising the role of context and culture and considering these in their evaluation of systems.

5 Educational Theories

Educational theories have always influenced work in educational technology. In this section, we will briefly describe the changes that have occurred over the past 20 years.

From the mid-sixties, the instructivist approach to designing learning situations was popular. However, constructivism has been the dominant paradigm in learning theories for the past 20 years. Its focus on considering how knowledge is developed by learners through experience has been a source of inspiration for educational technologists in the design of appropriate learning experiences. As has been reflected in our comments about theories in HCI, one of the most significant trends of the past 10 years has been an appreciation of the role of context and social processes in learning. In the late 80's a seminal paper in educational research Brown, Collins and Duguid (1989) outlined the assumptions of the situated learning approach. Even more recently, there has been increased attention paid to the role of social interaction in learning, largely based upon the work of Vygotsky, with an emphasis on the role of language and therefore dialogue. The implications of this shift have been well explored for educational technology in Jones and Mercer (1993).

Littleton and Hakkinen (1999) in their review of current research on collaborative learning explain the extent to which the dialogic view of knowledge construction has had an impact on research methodologies and data interpretation in this area. They conclude that studies influenced by Vygotskian theory have advanced our understanding of collaborative learning, but that to make progress, we need to integrate a fuller understanding of the cultural context of the learning situations.

6 Personal perspectives on theories used by educational technologists.

In this section we provide a brief overview of some of our own research as educational technologists. This is in order to illustrate the range of ways in which different theories and disciplines can be used for research within the field of educational technology. One of the purposes of this paper is to encourage educational technologists to go through a similar process of reflection on the sources of the theories which influence their work.

In our experience, as educational technologists, we have drawn on each of the theoretical perspectives we have so far reviewed in this paper, with the possible exception of the Ecological Psychology approach. Perhaps this is not surprising given educational technology's interdisciplinarity. Consulting colleagues recently, we found this to be a fairly typical position for educational technologists. We see the need for some research to develop a more informed perspective on the use of theories among educational technologist, and have embarked on a project to collect views from a larger and more diverse group.

We have both found an inspiration in work on cognitive modelling from the AIED tradition. For example, this was useful in conducting an examination of difficulties in novice physics problem solving which used cognitive modelling as an analysis framework for rich accounts of students' behaviour (Scanlon, 1990). A further example is provided in Issroff (1991) in which a system was designed to teach students about the Periodic Table, using a range of representations of the domain and providing different routes through the teaching materials which matched the students' learning styles.

Our view of theory has also influenced our collection of empirical data. In an investigation of affective factors in computer supported collaborative learning, we conducted two types of study. The first investigated the design aspects of a simulation of the Periodic Table, using a pre- and post-test design. Our dissatisfaction with ignoring the influence of the classroom situation on the research methods led to a second empirical study which required a completely different approach, involving a naturalistic setting with an emphasis on qualitative factors and an in-depth understanding of the students and the teachers' understanding of the learning situation (see Issroff, 1995, Issroff et al., 1997).

7 The role of theory in Educational Technology

There are no current accepted norms for the use of theories in educational technology. So, what should a theory in educational technology consist of or explain? It needs to be descriptive at minimum, that is it needs to be an account of students' learning experience which is not contradicted by empirical observations. The theory should explain, some if not all, how a particular example of teaching material could be expected to contribute to the students' learning experience. We are looking at how theories contribute to the design of different learning materials and how these designs in turn elicit different student behaviours – cooperation, motivation etc.

An educational technologist has to take a multi-leveled approach to understanding complex learning situations. Thus there is a need to consider the context of the institution, the culture of the students, the location of the learning situation within the curriculum as well as the design of the technology and software. In contrast, AIED with its focus on the design of systems incorporating educational and psychological theory is based on a smaller unit of analysis. The focus here is on the theories, the models and their instantiations within the systems, rather than the context in which they are used. HCI, similarly, has a focus on small units of analysis, with the main emphasis on the design of the systems and analysing the ways in which individuals interact with those systems.

These differences in the size of the units of analysis are reflected in the theories which are used by the different disciplines. It seems to us that one might even argue that there are two groups of theories in educational technologies: the first group are those which are used in HCI and AIED – ones which help us to design effective learning and teaching materials and systems. The second group are derived from education, and help us to understand the culture and context of different learning situations and their impact on students' learning. While the former group of theories can often by modified as a result of the empirical research carried out by learning technologists, the latter group of theories are not refutable. The two different groups of theories also have different functions, in that the former enable us to have theoretically informed designs of systems and materials, while the latter impacts on our empirical methodologies and our interpretations of data. It could be argued that theories such as situated cognition, which we would describe as a group 2 theory, vastly reduce the predictive capabilities of group one theories. The culture and context of learning situations will always differ and therefore findings from a study can only conclude that certain features will have an influence on the behaviour and learning of the students, but crucially will not be able to predict what that influence will be.

Recently, we have used Activity Theory to interpret some of this previous research and some of our more recent research (Issroff & Scanlon, 2001, Issroff & Scanlon, in press). This is an example of our use of a group 2 theory to try to understand the ways in which learning technologies impact on students' experiences, rather than to design effective materials.

8 Conclusion

Theories are an important, but neglected area in research in educational technology. In this paper, we have tried to reflect on the theories that currently influence us in our work as educational technologists. We feel the need for theories and models which will allow us to design and refine and validate examples of learning technology and to understand the experiences of users working in the new communications and computing infrastructure of modern higher education. We are conscious that the influences on us from current broader educational theories highlight the importance of social and cultural perspectives in analysing learning situations.

In this paper we have reflected on the different types of theories which have emerged from HCI and AIED and contrasted them with the theories which are dominant in education. The continuing conversation we wish to have about the role of theories will involve collecting experiences from the educational technology community about the affordances of different theoretical influences on their work.

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