CONSTRUCTIVISM: A SUITABLE PEDAGOGY FOR INFORMATION AND COMPUTING SCIENCES?

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ABSTRACT

Constructivism is a major intellectual influence on the development of modern learning technology. This paper first reviews the main tenets of the constructivist approach. The application of constructivism to the Information and Computing Sciences (ICS) is then critically discussed. It is argued that constructivism provides a set of ideas that should have a deeper and more widespread impact on ICS teaching and learning. There are many variants, however, within constructivism. The application of constructivism to ICS requires careful evaluation of the validity and applicability of the pedagogical ideas and principles proposed.

Keywords

Pedagogy, constructivism, learning environments

1. INTRODUCTION

Duffy and Jonassen [1] argue for a theory-based approach to instructional design. This theory concerns the assumptions about the learner and the learning process that underlie our design of instructional materials. Traditional Instructional Systems Design is criticised. The design strategies that emerge from this tradition emphasise the precise identification, efficient transmission and rigorous assessment of knowledge. Constructivism proposes a radically different perspective. The central tenet is that knowledge of the world is **constructed** by the individual. The person through interacting with the world constructs, tests and refines cognitive representations to make sense of the world. Constructive learning rather than instruction becomes the focal issue.

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This paper is set out in three main sections. The first section sets out the basic principles of constructivism. This is followed by a review of developments in ICS education directly influenced by constructivist pedagogy**.** This discussion provides exemplars of the application of more specific constructivist techniques, such as scaffolding. The final section discusses concerns and challenges in the application of constructivist pedagogy more widely within ICS Education

2. BASIC PRINCIPLES OF CONSTRUCTIVISM

The primary constructivist principles may be summarized under five headings distilled from the more extensive list given by Cunningham et al. [2]. These principles provide a useful framework for summarizing the constructivist proposals for learning environment design.

Authentic Learning Tasks: a central constructivist criticism of traditional formal teaching is that it is disembedded from the students' experience outside the classroom. The tasks lack meaning for the student. They argue that learning tasks should be embedded in problem solving contexts that are relevant in the real world. Learners must see the relevance of the knowledge and skill to their lives, and the leverage it provides in problems they see as important [3]. The tasks may be, for example, problem-based or case-based. These immerse the learner in a situation which requires the learner to acquire the knowledge and skills relevant to solving the problem [4].

Interaction: interaction is viewed as the primary source material for the cognitive constructions that people build to make sense of the world. Many constructivist theorists place particular emphasis on social interaction. Dialogue and the negotiation of meaning provide the basis for the individual to develop, test and refine their ideas. The traditional didactic mode of transmitting information in de-contextualised settings is rejected There are two main strands for developing interactive, social contexts for learning [2]. These strands focus on tutor - student relationships and peer group relationships respectively.

The first approach derives from the work of Vygotsky [5]. Vygotsky was concerned with the process of cultural transmission, and its role in cognitive development. The first type of 'collaborative configuration' is thus between a mature partner and a learner. The mature partner provides the principles which the learner acquires through structured social interactions. The clearest articulation of this approach is probably Cognitive Apprenticeship theory [6]. Cognitive Apprenticeship emphasizes the active role of the teacher in supporting the learner. The learner acts as an apprentice to the master craftsperson in the domain, i.e. the teacher. The teacher first provides a model of expert performance in the task. The teacher may do this by talking through a problem solution in mathematics, or the processes involved in composing an essay. The learner observes the model to build up a conceptual picture of mature performance in the domain. The teacher actively coaches the learner in acquiring the target skills and knowledge. The teacher then gradually removes this support, forcing the learner to become increasingly independent in their application of skills and knowledge.

The second type of social collaboration is between peers in a group. The proposal is that individuals can often learn best the processes of knowledge construction, negotiation and refinement in a community of peers. Group discussion is encouraged to elicit multiple perspectives and encourage the negotiated construction of meaning. The central constructivist themes of authentic activity, collaborative learning, and appreciation of multiple perspectives are emphasized.

Encourage Voice and Ownership in the Learning Process: the theme of student centred learning is continued with an argument that students should be allowed to choose the problems they will work on. Rather than the teacher acting as the taskmaster, the teacher should serve as a consultant to help students to generate problems which are relevant and interesting to them. It is argued that this is a vital part of solving problems in the real world.

Experience *WITH* the knowledge construction process: the emphasis on authentic tasks and rich interaction provides a base for experience ***with*** the knowledge construction process. There is a basic question here of what the outcomes of the learning process should be. Conventionally these outcomes would be defined in terms of the knowledge and skills the student has acquired. Constructivists argue that experiencing and becoming proficient in the process of constructing knowledge is more important. In other words it is learning how to learn, how to construct and refine new meaning that is most important.

Metacognition: this is the ultimate goal of a constructivist approach. Problem solving involves the processes of reflecting on problems and searching for solutions. Metacognition is the higher order process of reflecting on our own thinking and problem solving processes. Cunningham refers to this ability as reflexivity. Metacognition has powerful problem solving potential. If we are stuck with a problem we can reflect not just on the structure of the problem, but on the structuring of our approaches to the problem. We can then try to generate alternative, more productive strategies. However, this is viewed not just as a useful problem solving ability, but the ultimate expression of education - the ability to reflect back on what has been created by the process of education. This opens up opportunities to transform our understanding and to 'liberate' ourselves from prior ways of thinking.

3. APPLICATIONS OF CONSTRUCTIVISM IN INFORMATION AND COMPUTING SCIENCES

Ben-Ari [7] argues that constructivism has been extremely influential in science and mathematics education, but much less so in computer science education. He argues for the relevance and importance of constructivist ideas for improving the education in computer science. Although Ben-Ari is correct in that the systematic impact of constructivism on ICS Education has been weak there are a number of notable exceptions. These range from the ideas of Papert, which underpin the development of Logo, through the teaching of programming and software design, to collaborative learning using the Web. These examples are briefly discussed to illustrate the potential of constructivist ideas in ICS education.

Papert was strongly influenced by a Piaget, in many ways the founder of constructivist epistemology. Logo was designed as a programming language for schoolchildren [8]. Many of the basic design features of Logo are constructivist in nature. There is a strong emphasis on the children constructing their own knowledge of the language and how to use it to solve problems. A number of the design features of Logo were developed to facilitate this process. There is a strong emphasis on supporting the transition from the child's present state of knowledge to more abstract and formal understanding. Strong visual feedback is provided in the form of Turtle Graphics to enable the child to visualize the impact of the instructions they write. This in turn provides a basis for a learner-centred recognition and debugging of errors. Errors are treated not as 'mistakes' as in much formal computer science education, but rather as a natural and productive part of learning.

Logo provides an example of a general feature of constructivist approaches to education. This is to provide rich resources to enable the construction of meaning by the learner. Built into this approach is the recognition of the need to support the learner in moving from their initial state of knowledge to more abstract levels of understanding. One product of this approach was the development of the concept of Microworlds. These enable learners to visualize the impact of the changes they make in a formal system such as a programming language. This idea has influenced university level approaches to the design of learning environments for programming (e.g., [9]).

The CORE approach provides another constructivist inspired approach to the development of learning environments for programming. The central idea of the CORE approach is that the learning of a formal computer language could be modeled on the learning of natural language. Studies of natural language acquisition have revealed that children are highly creative in the process. They infer rules based on the speech they hear. When they produce utterances based on these rules they frequently make 'errors'. Feedback from adults helps the children to refine their understanding to converge on the adult model of the language. The CORE approach aims to replicate this dynamic process.

In the CORE approach the pedagogical emphasis is on enabling the learner to construct their own understanding of the rules of their language. This is achieved by presenting carefully chosen sequences of micro-problems based on examples. The learner develops and refines their understanding based on the feedback they receive in attempts to solve these problems. Each learning block culminates in the learner expressing the competence they have acquired by writing a program which requires the use of the new construct [10,11].

The CORE approach was first developed to support the learning of formal computer languages. This resulted in a commercial system for learning Pascal [12], and in the hypertext based CLEM system which has been used continuously for over nine years [11]. This approach was subsequently applied to a range of domains outside ICS education, such as behavioural ecology [13] and nuclear medicine [14].

Constructivist principles, however, have been applied more broadly. They have influenced approaches to designing learning environments for object-oriented concepts [15] and design (e.g. [16]). The 'softer' information system side of the discipline has also been affected by ideas based on enabling students to find their own problems and work collaboratively to produce solutions. The theoretical influence of constructivism gels well with the pragmatic pressures from employers to produce students who can communicate, collaborate, and solve real-life problems. The use of Web-based computer conferencing has provided a technological impetus to further experimentation in this area, e.g. [17]. In this area ICS can learn from the extensive work carried out in other disciplines.

4. CONCERNS AND CHALLENGES IN THE APPLICATION OF CONSTRUCTIVISM

Cunningham [3] emphasizes that constructivism provides a clear theory-based approach for design. However, this theoretical base reflects a mixture of influences. Can we make an informed choice as to which aspects of constructivism are most strongly based and most useful in ICS education?

Ben-Ari [7] provides a set of arguments for how constructivism can be applied to more formal computer science education. He argues that much knowledge in computer science is not open to social negotiation. The user cannot argue that a program construct is incorrect, and present that as the reason for the program failing. There are more definite and immutable criteria for what is correct in writing a program than in discussing alternative designs in an innovative information system. Ben-Ari emphasizes that the construction of knowledge in areas such as programming must be guided by a teacher. He advocates, in particular, making explicit clear models that enables students to construct more accurate mental representations of the behaviour of the computer. This, in turn, will provide them with a cognitive basis for understanding and debugging the behaviour of programs. He argues, however, that these models simply cannot be transmitted through didactic methods of teaching. The teacher must carefully design experiences which help students to build on their present knowledge base. In this process 'errors' are seen as the result of systematic, if incorrect, models of the behaviour of computer. The teacher must be sensitive to the constructive processes in which learners are engaged; the tutor should provide feedback that supports students in recognizing the limitations of their current models, and guidance on how to develop more accurate mental models.

Crawford [18] deals with a much wider domain: the teaching of IT in secondary schools. He advocates the necessity of taking a constructivist approach. Knowledge of IT, for example, changes very quickly, e.g. the explosion of knowledge associated with the Internet. A focus on the learning and reproduction of factual knowledge is thus not helpful. Both teachers and students will have to constantly relearn their subject skills and knowledge. The constructivist emphasis on learning problem-solving skills rather than factual knowledge thus seems appropriate. Crawford culminates his article with the concrete list of recommendations. Many of these ideas are equally applicable to higher education. These guidelines include: set authentic tasks that nurture students' curiosity; use errors as a productive part of the learning process; emphasize knowledge construction not reproduction, and encourage dialogue and collaborative learning [18, p.10].

5. SUMMARY

This paper has outlined the main pedagogical principles of constructivism. There is considerable richness in constructivist approaches to learning strategy choice and realization. The application of these ideas to teaching and learning in ICS has been discussed and illustrated. These ideas provide considerable scope for improving the pedagogy of ICS education. Constructivism is itself, of course, a construction. There is a need to engage in ongoing debate to develop a constructivist framework adapted to the needs of ICS.

6. REFERENCES

[1] Duffy T. M. and Jonassen D. H. (1991) *Constructivism: new implications for educational technology?* Educational Technology, 31, 5, 7-12.

[2] Cunningham D. J., Duffy T. M and Knuth R. (1993) The textbook of the future. In C. McKnight, A. Dillon and J. Richardson (eds) *Hypertext: a psychological perspective*. Ellis Horword.

[3] Cunningham D. J. (1991) Assessing constructions and constructing assessments: a dialogue, *Educational Technology*, **31**, 5, 13-17.

[4] Jonassen D. Mayes T. and McAleese R. (1993) A manifesto for a constructivist approach to uses of technology in higher education. In Duffy T. M., Lowyck J., Jonassen D. H. and Welsh T. M. (Eds) *Designing Environments for Constructive Learning.* Springer-Verlag.

[5] Vygotsky L. S. (1962) *Thought and language*, MIT Press, Cambridge, Mass

[6] Collins A., Brown J. S. & Newman S. E. (1989) Cognitive apprenticeship: teaching the crafts of reading, writing and mathematics. In L. B. Resnick (ed.) *Cognition and Instruction: issues and agendas*. Lawrence Erlbaum Associates.

[7] Ben-Ari M. (2000) Constructivism in Computer Science Education. *Accepted for publication in the Journal of Computers in Mathematics and Science Teaching.*

[8] Papert S. (1980) *Mindstorms: children, computers and powerful ideas*. Basic Books.

[9] Brusilovsky P, Kouchnirenko A., Miller P. and Tomek I. (1994) Teaching programming to novices: a review of approaches and tools. In T. Ottmann and I. Tomek (Eds) *Educational multimedia and hypermedia: Procs of Ed Media 1994*. AACE.

[10] Boyle T., Gray J., Wendl B. and Davies M. (1994) Taking the plunge with CLEM: the design and evaluation of a large scale CAL system, *Computers and Education*, **22,**19-26.

[11] Boyle T. and Davies M. (1996) Hypermedia environments for learning to program. In P. Brusilovsky, P. Kommers and N. Streitz (eds) *Multimedia, hypermedia and virtual reality*. LNCS 1077. Springer.

[12] Boyle T. and Margetts S. (1991) *Pascal by active learning using the CORE approach*. D. P. Publishing.

[13] Boyle T., Stevens-Wood B., Zhu F. and Tikka A. (1996) Structured learning in virtual environments, *Computers and Education*, **26**, 1/3, 41-49.

[14] Hogg P., Boyle T. and Lawson R. (1999) Comparative evaluation of a CORE based learning enviroment for nuclear medicine. *Journal of Educational Multimedia and Hypermedia*, **8**, No. 4, 457-473.

[15] Alpert S. R., Singley M. K. and Carroll J. M. (1995) Multiple multimodal mentors: delivering computer-based instruction via specialized anthropomorphic advisors, *Behaviour and Information Technology*, **14**, No. 2, 69–79.

[16] Yazici Z. and Boyle T. (2000) A multimedia learning environment for Object-Oriented design. *Submitted to 8th Annual Conference on the Teaching of Computing*

[17] Cook J. and Boyle T. (2000) Effective delivery of on-campus networked learning: reflections on two Case-Studies. Presented at the 2nd International Conference on Networked Learning, April 17 to 19th 2000, University of Lancaster.

[18] Crawford R. (1999) teaching and learning IT in English state secondary schools- towards a new pedagogy, *Education and Information Technologies*, **4**, pp. 49-63

(also: http://www.hud.ac.uk/ITsec/itped.htm)