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Challenges for design of computer-based learning environments

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Abstract

After several decades of learning research and the reactions of cognitive psychology to this research, educational psychologists and training designers developed prescriptive model for the systematic design of instruction (Derry and Lesgold, 1994). This model, called Instructional Design (ID) or Instructional System Design (ISD), consists of knowledge, terminology and procedures that are widely accepted by professionals within the instructional design culture (eg, Dick and Carey, 1990; Gagne and Merrill, 1990). Designing instances of instruction or planning and preparing to instruct can be considered a subset of designing. Instructional design is directed toward the practical purpose of learning; the instructional design process aims at creating new instructional materials or systems with which students learn (Rowland, 1993). The process of instructional design attempts to develop an understanding of the conditions and desired outcomes of instruction, and to use all of this in specifying methods of instruction (Reigeluth, 1983). With the rising interest in more open, often computer-based learning environments, traditional definitions of instructional design need adaptation and more sophisticated models of design have been called for (Hannafin and Land, 1996; Lowyck and Pöysä, 2001; Reigeluth, 1996 and 1998). This paper presents a review of the basic foundations and more recent challenges of the main instructional design traditions.

Introduction

The original idea of instructional design by Gagne (1985) divided ID into several steps:

1. analyze the domain knowledge into a hierarchy of atoms which are either a small piece of knowledge or a simple combination of previously specified atoms

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2. sequence the atoms for instruction so that a combination atom is not taught until its components have been taught, and
3. design an instructional approach for each atom in the sequence. In many ID models, the procedure is also divided into three phases: task analysis, selection/ creation of method, and evaluation (see Andrews and Goodson, 1981). Task analysis identifies the factors (eg, students' prior knowledge) that need to be taken into account when the methods are selected. Instructional methods and strategies are selected or created by using some prescriptive instructional theory, experience and conventional wisdom. And before final implementation, instructional prototypes are tested and revised.

Although this kind of systematic design of instruction has its advantages, it also raises serious problems, and several researchers have recently called for a new paradigm both of instructional theory and of ISD processes (Hannafin and Land, 1996; Lowyck and Pöysä, 2001; Reigeluth, 1996 and 1998). In the most critical views, it is claimed that research on instructional design usually shows hardly any cognisance of student learning, or of anything that would help a teacher to design instruction that facilitates deep rather than surface learning (eg, Kember and Murphy, 1990; Reigeluth, 1983). Many instructional design methods and products are still rather convergent and reductionist (eg, Winn, 1993). Instructional design has too often leant on detailed examination of minor topics that are often influenced by Gagne's (1985) theory of hierarchical sequencing. It has often been concluded that the Instructional System Design (ISD) is a set of methods, materials and assessments aimed at promoting competence in defined outcomes. Traditional ID methods and models have been considered to be externally directed and content driven (eg, Hannafin, 1993; Johnson and Taylor, 1991).

Instructional designers are claimed to structure both the content and the methods used to convey lesson content. Content is organized into instructional sequences, and learners proceed through prescribed sequences. In cases where the external structuring of knowledge and learning of clearly specified content are required, such methods are effective (Hannafin, 1993). However, learning goals and activities are nowadays often less explicit and identifiable, while being more complex, individual and internally centered, than when addressed via instructional design methods (Kember and Murphy, 1990). The problems of instructional design get stressed mainly when the aim is to design effective environments for more complex cognitive tasks (eg, Lowyck and Elen, 1994; Willis, 1998). Instead of building competence according to external conventions, learning environments should induce learning through largely internal mediation (Hannafin, 1993).

Alternative approaches

The field of instructional design has developed since the first models were produced. Although the roots of traditional ID models can be found in behaviorism, also Gagne and Merrill (1990) have demanded later that human performance has to be treated at a higher level of abstraction than is usually done in the models of instructional design. They have emphasized the application of complex sets of knowledge and skills rather than the acquisition of knowledge and skills in isolation. Current notions of learning

have challenged instructional design dramatically, but there is still a great diversity of theoretical stances in the field (Duchastel, 1998). Theoretical stances differ mainly with respect to selection of different views on learning and instruction. For example, elaboration theory emphasizes contextualizing knowledge elements within their holistic topical structures (Reigeluth, 1998), whereas constructivism emphasizes authentic problem-solving (Jonassen, 1998).

The main aim in most of the ID models has usually been to describe the major elements of an instructional environment. There is, however, no agreement in the field of learning research on what the important variables are (Lowyck and Elen, 1994). Of course, instructional environments can be described, but the question arises as to whether they can be described in a meaningful and "objective" way from the standpoint of learning and instruction. In the recent views, eg, cognitive, social and affective dimensions of instructional design have been emphasized (Lowyck and Elen, 1994; Reigeluth, 1996).

Lowyck and Elen (1993) among others have focused on learner-related parameters as the starting point of instruction in which learners are able to control the amount and flow of information. A combination of learner characteristics is selected that is assumed to account for the variation in the ability and motivation of learners to engage in appropriate cognitive processes. For instance, prior knowledge, motivation and metacognition are seen as important parameters in cognitive models of instructional design. Reigeluth (1996, 1998) has called for a new paradigm of instructional theory that would focus on customized learning that fosters empowerment, initiative, and responsibility, as well as teamwork, thinking skills, metacognitive skills and diversity. Reigeluth (1996) has also suggested that we should encourage instructional theories in a wide variety of different areas, and in addition to cognitive domain, also the affective domain should be emphasized.

Duffy and Bednar (1991) have suggested making a transition from structuring instruction to designing environments in which learning can take place. For instructional practices this means that the goal of instruction is no longer primarily to impart new knowledge in a readily accessible form but to facilitate the student's own attempts to construct meaning. Thus, the question of "How to carry out task analysis, method selection and evaluation" could be transformed into the question: "How can we create situations which facilitate learning?" The focus has clearly moved to design of more complex realities like learning environments instead of programmes, methods or tools.

The role of instructional interventions

The need for instructional support in learning environments has been one of the key factors in instructional design models and methods. Research made in open learning environments has demonstrated the difficulties generated by these environments (Hannafin and Land, 1996). Whereas in earlier views the learner was regarded as reactive and instructional support devices were constructed primarily into instructional environments, the active view of the learner has challenged the need for these interventions. It seems obvious that instructional support by teachers is necessary for effective

learning in open technology-based environments (Hativa and Becker, 1994; Mercer and Fisher, 1992). Furthermore, external agents such as teachers or instructional materials are viewed more as activators of learning than mediators of knowledge (Hannafin, 1993).

Apparently there are some necessary conditions, which must be fulfilled in open environments in order to produce a positive influence on learning outcomes. These include, first, guidance and individualized support by the teacher. Second, it has been demonstrated that open environments have positive effects on learning outcomes among those students who have good prior knowledge and specialized expertise. Students representing a low level of achievement attain poorer outcomes in open and very unstructured environments compared to more structured environments (Mandl *et al,* 1994). Many students, for example, might not be able to make effective choices during the lesson. One reason for this could be that effective student choices are often related to prior knowledge and therefore student-centered environments might sometimes prove inefficient (Merrill *et al,* 1990). On the other hand, powerful learning environments are generally thought to be environments where appropriate teaching strategies are essential. Thus, suitable ways of organizing learning can take students' prior knowledge into account and accommodate interventions on the basis of this. Reigeluth (1996) has suggested that instructional theories should offer guidelines for the design of learning environments that provide appropriate combinations of challenge and guidance, of empowerment and support as well as of self-direction and structure. The mixture of ambition and complexity, of external structure and self-regulation, of curriculum and co-construction of knowledge calls for new visions on and approaches of design (Lowyck and Pöysä, 2001).

It is also evident that instructional support might be beneficial for some learners but harmful for others (Clark, 1989). Furthermore, constructivists have claimed that it is up to the learner whether (s)he will use the support, for what reason and at what time in the learning process (Perkins, 1991). In addition, students' opinions about the components of instructional environments often differ from those of designers (Winne and Marx, 1982). It can also be hypothesized that the lack of correspondence between learners' and designers' instructional frameworks results in a lack of clear effects (Lowyck and Elen, 1994). Thus, a learner's perspective should also be represented in instructional theory with respect to the description of instructional environments. Lowyck and Elen (1994) also argue that if more were known about the learners' interpretations of instructional interventions, it would be easier to design instruction.

Recent challenges for the field of instructional design

A typical field for applying ISD models and methods has been computer-based instruction. Furthermore, the rapid advance in technology itself has influenced the design of computer-supported learning environments. Unfortunately, hardware technology has too often been harnessed merely to accommodate to the traditional conceptions of learning (Hannafin, 1993). It has been easy, but not very challenging way to use the potential of new technology to improve the quality of learning. However, recent

technological developments have markedly expanded the designer's toolkit. Hybrid, computer-based instructional systems called emerging technologies, emphasize creating functions and attributes across developing technologies that also represent the technological capacity to present, manipulate, control or otherwise manage educational activities (Hannafin, 1993).

There are also viewpoints on whether computers themselves elicit productive learning or not. At the one extreme, Clark (1989) claimed that educational media are merely vehicles that deliver instruction but do not influence learning under any conditions. According to this claim, the content and method of instruction are the most important factors, although the medium can influence the efficiency and the cost of delivering instruction. Kozma, (1992), however, has argued that in a good instructional design, the medium and the method are closely integrated and the learner constructs knowledge in interaction with the medium and the method. According to recent views, it is not the technology alone that affects learning but the whole system of correlated variables such as technology, activity, goals, setting, teacher's role, classroom culture etc, which exerts combined effects (Salomon *et al,* 1996).

In addition, Hannafin (1993) stated that with emerging instructional technologies the shortcomings of traditional ISD models have become more apparent. Although some attempts to promote intellectual development have been challenged within the field of ISD (eg, LOGO), the contradiction between student-centered and instruction-centered learning is still wide (eg, Duffy and Jonassen, 1991; Perkins, 1991). Several attempts have been made to describe alternative directions for instructional designs in the spirit of modern technological advances (eg, Cognition and Technology Group at Vanderbildt, 1993; Duffy and Jonassen, 1991; Merrill *et al,* 1990; Perkins, 1991; Scardamalia and Bereiter, 1996). For example, the potentials of networked learning environments have offered tools for joint workspaces and reflective communication, which enable individuals to share cognitive load with other individuals or in some cases with intelligent technology. Skilful exploitation of these tools offers new possibilities for design of powerful learning environments.

Challenges for the field of instructional design have also been set by the evolvement of the theories of learning and design. Recent emphasis on socio-constructivist and situated theories of learning and design has focused on co-construction of knowledge and co-design of learning environments (Dillenbourg, 1999). Focus on social dimension of learning confronts instructional designers with the challenge of building interactions between learners and their environment. Even the concept of designing for "learning communities" has become more common (Schwier, 1999). When emphasis has been placed on design of learning environments rather than on design of instructional devices, new challenges are also set for the design process. In order to succeed, the design of educational software for powerful learning environments should be considered to a great extent as a social process. Design and use of educational software are fields where various people are dealing with the same activities. Banathy (1991) described design of educational systems as a future-creating, disciplined inquiry where members of the

design team share a vision of education, collectively define its purposes and engage in the design of a system that fits their vision and purpose.

Reigeluth (1996) has claimed that users play a greater role in designing their instruction than what the current conception of ISD allows. The ideas of participative or participatory design are no longer new concepts in systems design (eg, Grudin, 1990). Furthermore, there have been discussions of cooperative design (Bodker and Gronbaek, 1991). Brown and Duguid (1994) have suggested fundamental redirection of the way designers look at artifacts and users. They propose a framework that deals with the notion of a border between artefact and context, which is a resource for both users and designers. They suggest that designers should understand more fully the role played by border resources and work more directly to help users develop these resources. Designers need to look beyond the object and engage more closely in the social contexts of use (Brown and Duguid, 1994; Soloway *et al,* 1996). Furthermore, they need to respond to communities of users, the negotiations members undertake and the genres they develop. To sum up, also instructional design is nowadays interpreted more as non-linear, cyclical and iterative process. Design is externally controlled endeavour, but at the same time an adaptive and iterative process where learners, peers, tutors, teachers and parents play their roles. Also the concept of "user-designers" has become more referred in ISD field. This kind of user-based approach suggests us to put better design tools and knowledge in the hands of those who generally create and deliver the instruction anyway (eg, teachers).

Conclusions

Although prescriptive models are still implicitly represented in the ways many (but not all) instructional designers design instructional prototypes, design is no longer an intuitive endeavour with a lot of variability in its knowledge base. Designing environments for learning is dependent upon the descriptive knowledge base on learning and instruction, and it consists usually of task-analysis, problem-solving and testing by a team of experts in complex domains. One of the major challenges for the field of instructional design is to seriously recognize the importance of participatory and collaborative modes of designing. Explicit thinking about the border between the design artefact and its context of use is needed. However, as Duchastel (1998) and Reigeluth (1998) have brought out, the use of instructional theory involves choices that are rooted in beliefs about values to underlie education for instance. Also designer's conceptions of learning (either explicit or implicit) have influence on design decisions. Altogether it is important to bear in mind that the quality of instructional design is highly dependent on the fit between the design model and its "intelligent" use by the designer (Häkkinen, 1996; Lowyck and Pöysä, 2001).

Instructional design has been influenced by research and development both within and outside the field of instructional design. Hannafin (1993) stated that instructional designers have not been very open to new alternatives; they have not reassessed the basic foundations or assumptions of the models, which can be seen as the third major challenge. Objectives, learning hierarchies and sequences, and emphasis on convergent

instructional activities have become all too self-evident components of instructional design. The field of instructional design has developed separately from other theoretical orientations such as research on artificial intelligence, organizational learning and collaborative teaching and learning. Thus, the main problem of instructional design has been its isolation from other fields of teaching, learning and technology. However, in the recent discussions on instructional theories and instructional design processes, a wide variety of theories and views have been presented. Diversity of theoretical stances focuses on cognitive, affective and/or social dimensions of learning. The interplay of different theories is necessary in the design of complex, often open-ended and collaborative learning environments, but it is also a big challenge for instructional designers.

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