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Three worlds of instructional design: State of the art and future directions

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Abstract. Three worlds of ID are distinguished. The World of Knowledge stresses the analysis of learning outcomes in knowledge structures and the selection of instructional strategies for particular outcomes; the World of Learning focuses on particular learning processes and the synthesis of strategies that support those processes; the World of Work focuses on real-life task performance and strategies that support learners while they work on authentic problems. Contributions to this Special Issue are discussed within the three-world framework. Implications for future research are discussed, stressing the promise of mental models as a theoretical construct that may help to build bridges between the three worlds.

Keywords: cognitivism, constructivism, instructional design, instructional methods, learning, mental models

Introduction

"How to help people learn better. That is what instructional theory is all about" (Reigeluth, 1999, p. ix). Although the authors in this Special Issue will probably all agree with this, they nevertheless present diverging instructional theories and approaches as to how it should be done. The main question that will be answered in this Summary and Discussion is how this divergence is possible. It will be argued that the different authors are performing their research and development work in different Worlds of Instructional Design (ID). Building on a distinction between three such worlds, the contributions are discussed and some directions for future research that may possibly help to take the field of Instructional Design one step further are sketched.

Several contributions put forward useful dimensions for our purpose. For instance, Spector sketched three ontological perspectives with implications for ID: A Cartesian approach that is mainly analytic in nature, an action-theoretical approach that is mainly synthetic, and a currently re-emerging classical approach that is mainly holistic. Merrill argued that the 'what-to-teach' question is, next to the question of how to help people learn better (i.e., the 'how-to-teach' question), another fundamental issue in ID. Those

Analyze the requirements for learning by working back from the intended learning goal
1 Identify the types of learning outcomes we wish to achieve.
2 Break learning outcomes down into a hierarchy of dependent learning outcomes and pre-requirements, to give a learning hierarchy of simple outcomes.
3 Identify the conditions or processes internal to the learner that must occur to achieve those outcomes.
4 Specify what external conditions or instruction must occur to achieve these internal conditions.

Select the media
5 Record the learning context.
6 Record the characteristics of the learners.
7 Select media for instruction.

Design the instruction - Plan instructional events to support learning activities
8 Plan to motivate the learner by incentives, task mastery or achievements.
9 Design instructional events relevant to the type of learning outcomes required for each of the planned learning outcomes in the learning hierarchy, in the order of pre-requirements in the learning hierarchy, and with appropriate media and use of tutors.
10 Test the instruction in trials with learners (formative evaluation).
11 Judge the effectiveness after the instruction on has been used via summative evaluation.

In brief, Gagné's ID produces an analysis of the learning to be accomplished (1-6) and then translates this into a design for instructional events which will prompt and support the internal processes of the learner (7-9). These are then tested, used and evaluated (10-11).

Figure 1. Instructional Design according to Gagné.

two questions are clearly interrelated. In regular schooling, the what-to-teach question typically boils down to a description of knowledge and basic skills. In industrial training or higher vocational education, the answer often refers to a description of real-life task performance and complex professional skills. This will probably affect the answers given to the how-to-teach question. Theories and models of ID, thus, come in many different types, situating ID in different worlds. For the purpose of this article, a distinction is made between the World of Knowledge, the World of Learning, and the World of Work.

The *World of Knowledge* is most easily associated with the traditional field of ID, where foundations were laid by Gagné (1965, see Figure 1). In this world, the common answer to the what-to-teach-question rests on taxonomies of learning outcomes, typically referring to particular knowledge elements (e.g., concepts, rules, strategies, etc.). Taxonomies of learning have a long history. Bloom (1956) and Gagné (1965) introduced taxonomies that are still widely used. Gagné also made clear that specific learning outcomes can often only be determined on the basis of some kind of task analysis. He introduced the 'learning hierarchy' as a means of task decomposition. This hierarchy holds that a more complex intellectual skill is at the top and enabling skills are lower in the hierarchy. Later ID models further refined taxonomies of learning (e.g., Merrill's performance-content matrix, 1983) and detailed out the task-analytical procedures necessary for reaching a highly specific description of 'what-to-teach' in terms of particular learning outcomes (e.g., Leshin et al., 1992).

In the World of Knowledge, the common answer to the how-to-teach question rests on Gagné's idea of 'conditions of learning'. Theories for the design of instruction in the World of Knowledge presume that the optimal conditions for learning mainly depend on the goal of the learning process and that by analyzing the goals of education instructional designers can devise methods for the achievement of these goals. They assume that designers can describe a subject matter domain in terms of learning goals, and can then develop instruction for each of the learning goals – taking the optimal conditions of learning for each goal into account.

The *World of Learning* is, not surprisingly, mainly rooted in educational and cognitive psychology. The focus is on the analysis of learning processes. Not an analysis of the content, but a study of the process of learning is the starting point for design. Examples can be found in research on reading comprehension, which yielded guidelines for the optimal design of texts; research on the acquisition of procedural skills, which yielded guidelines for the design of drill-and-practice computer programs, or research on discovery learning, which yielded guidelines for the design of computer-based educational simulations or discovery worlds. While the World of Knowledge is heavily involved with task and content analysis in order to specify learning outcomes, the World of Learning is mainly involved with specifying the instructional conditions that may help to support a particular, often pre-defined kind of learning process.

In the World of Learning, the 'how-to-teach' question is thus typically rephrased as a 'how-to-support-learning' question. In the World of Knowledge, instructional strategies often take the form of delivery methods, specifying how to optimally deliver presentations, how to set up practice and how to assess for particular learning outcomes. In the World of Learning, instructional strategies mainly pertain to methods that support specific learning processes. The focus is on the development of support systems, often called cognitive tools or learning tools, and feedback strategies.

Finally, in the *World of Work* the common answer to the what-to-teach question rests on a description of real-life or professional tasks. This world is best associated with constructivist views on learning based on the idea that learners construct knowledge based on their own mental and social activity. Constructivism holds that in order to learn, learning needs to be situated in problem solving in real-life, authentic contexts (Brown et al., 1988) where the environment is rich in information and where there are no right answers (embedded knowledge).

In answering the how-to-teach question, theories within the World of Work take the viewpoint that complex knowledge and skills are best learnt through cognitive apprenticeship on the part of the learner in a rich environment (Collins, 1988). Experiences are provided for the learners that mimic the apprenticeship programs of adults in trades, or teachers in internship. Although it is not possible to submerse the learner to the extent that an internship would imply, through the use of simulations and meaningful experiences, the learner would learn the ways of knowing of an expert. Meaning is negotiated through interactions with others where multiple perspectives on reality exist (Von Glasersfeld, 1988). Reflexivity is essential and must be nurtured (Barnett, 1997a,b). Finally, all of this is best – and possibly only – achieved when learning takes place in ill-structured domains (Spiro et al., 1988).

Summarizing, there appear to be at least three Worlds of ID. The World of Knowledge stresses the *analysis* of tasks and content in learning goals and prescribes optimal instructional methods for particular learning goals. The World of Learning stresses the characteristics of particular learning processes and yields guidelines for the *synthesis* of learning support systems, in particular, learning environments. Finally, the World of Work takes a *holistic* viewpoint and stresses real-life, professional task performance and instructional strategies that may help to deal with the complexity of whole-task performance. The next section discusses the contributions to this Special Issue and positions them in the three-world framework.

State of the art

The contribution of Merrill, ‘Components of instruction toward a theoretical tool for instructional design’, is an excellent example of a very powerful ID model situated in the World of Knowledge. It opens with a citation of Wilson (1998), stating that the cutting edge of science is reductionism. This clearly reflects the analytic approach of CDT_2, the ID-model presented in this article. A taxonomy of learning outcomes is presented using the concept of ‘knowledge components’, that is, containers that precisely describe the to-be-taught content. This supports a process of cognitive task analysis (CTA; see Figure 2 for an example). While this is not elaborated on in the article, the model also allows for teaching medium-sized, integrated sets of knowledge components. Furthermore, the model is in line with Gagné’s conditions of learning. It proposes different combinations of instructional strategies and knowledge components for different instructional goals. Clear lesson examples are provided to illustrate this principle.

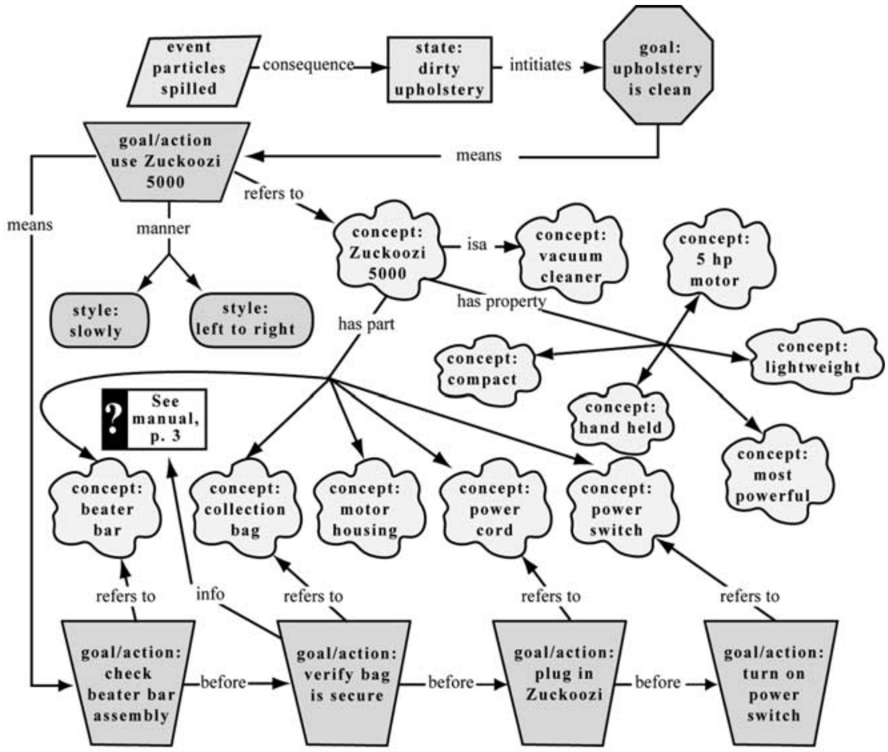

Figure 2. Cognitive task analysis of what needs to be learnt to operate a Zuckoozie vacuum cleaner (from http://edweb.sdsu.edu/T3/Module5/ET544v2/Dir/DirCTA).

CDT_2 is extremely useful for traditional lesson design primarily because it deals with entities, actions or processes that can be learned in a limited time span. However, its major strength, namely its analytic approach, is at the same time its major weakness. This can be illustrated by another citation of Wilson (1998) given at the end of the article: "…the reduction of each phenomenon to its constituent elements, [is] followed by the use of the elements to *reconstitute* [italics added] the holistic properties of the phenomenon". This process of reconstitution works well for a limited set of elements. The question is: How can reconstitution be reached when designers are dealing with complex learning, such as the acquisition of complex cognitive skills, that may require hundreds of hours of training before a basic level of proficiency is reached? For complex learning, instructional designers are facing extremely large sets of highly integrated knowledge components. To do this, they need to synthesize many instructional strategies that are all necessary to reach multiple learning goals. While CDT_2 is very helpful for the analysis of learning goals and the apportioning of these goals into their constituent elements, it provides far less guidance for synthesizing these elements and their associated instructional strategies.

Scandura describes another example of an ID-model situated in the World of Knowledge in his contribution 'Structural Learning Theory: Current status and new perspectives'. Structural Learning Theory (SLT) was originally developed in the early 60s and has continued to develop through to the present. Its relevancy can be seen in that some of its main characteristics have been surprisingly stable throughout this period. As in CDT_2, SLT adopts an analytic approach, but the emphasis here is more on complex behaviors. First, it provides powerful procedures and tools (e.g., AutoBuilder) for structural analysis. This task-analytical method yields a description of complex behaviors in terms of rules and higher-order rules, which enable designers to talk about complex behaviors at different levels of abstraction. This method can be seen as a refined version of production system analysis (e.g., Anderson, 1993). Second, it strongly emphasizes the role of prior knowledge in learning. This leads to a third, major idea in SLT, namely that learner diagnosis is made very effective by assessing prior knowledge, or the current knowledge state of a learner, at multiple levels of abstraction. If a learner is successful on a set of rules in the middle of a difficulty hierarchy, then he is almost certainly able to solve tasks associated with rules that are subsets hereof.

The focus of SLT on runnable, rule-based representations of complex behaviors (e.g., problem solving) and learner diagnosis is representative of the field of Intelligent Tutoring Systems (ITS). In fact, SLT provides a foundation for much of the work that is currently being carried out in this field. Two critical comments need to be made here. First, the advantage of a runnable, rule-based representation is that it insures that a task analysis is complete. This advantage, however, hardly makes up for the disadvantage that such a simulation often requires a tremendous amount of effort to implement, making it less useful for the everyday design of instruction. It may be an advantage when building advanced training systems for highly critical skills. Second, the focus on cognitive task analysis and learner diagnosis common to the field of ITS tends to over-emphasize feedback and support strategies while neglecting many other important instructional strategies. Both CDT_2 and SLT provide little guidance for how to synthesize the large amount of instructional strategies that may help to make learning more effective, efficient and appealing.

The ID-model used by Kuyper, De Hoog & De Jong described in their article 'Modeling and supporting the authoring process of multimedia simulation based educational software: A knowledge engineering approach' is a good example of the sound application of the World of Learning. The simulations that they develop are rooted in instructional events which occur in laboratory classrooms rather than in real life events. The instruction that they design is directed at the acquisition of understanding of concepts required by the educational curriculum. They describe in their article the use of SIMQUEST, an authoring and development tool, which makes use of cognitive tools and support for discovery learning environments. Their starting point is not the real world, but rather the design space.

First an instructional model is determined covering 'those aspects that are relevant from the learning point of view'. These include the traditional steps of structuring the concepts by first decomposing the concepts into learning goals and subgoals and then determining the (inter-)relationships and dependencies between the concepts. Having done this, a simulation model is developed based upon the developed instructional model. This is finally followed by the determination of the interaction model that captures the interaction elements available to the learner.

It is interesting to note that Kuyper et al. take a very clinical, synthetic approach to the design of instruction. While the focus in the World of Knowledge is on 'pre-authoring', that is, the analysis of content, tasks, context and target group, the focus of the World of Learning is on authoring and authoring tools. It seems that the primary role of the real world is to provide a setting in which the curricular goals of the intended education can be applied. Context is, for these authors, primarily the organizational context in which the authored simulation will eventually be applied.

The approach of Kuyper et al. is in sharp contrast to the approach chosen by Frank Achtenhagen in his contribution 'Criteria for the development of complex teaching-learning environments'. He begins with a critique of the traditional didactic view of the importance of goals and content. He calls this a 'lack of curricular considerations in the field of instructional design'. He is in the first place interested in how instruction can and should be embedded in the real world, which positions his work in the World of Work. This is a step that precedes traditional steps such as needs assessment and task analysis. He further modifies the World of Learning approach by posing an ID-approach based upon a two step approach to didactic modeling, namely modeling reality and then modeling those models of reality from a didactic perspective. This modeling of the model for didactic purposes allows the designer, for example, to determine which elements of the original model can be omitted, and what elements can be made abundant (not in the original, but introduced for supporting the functions of the model). The determination of these aspects is based upon a neopragmatic approach to modeling (Stachowiak, 1973) in which the feature of *pragmatic purposes* allows for the non-ambiguous, sometimes embellished assignment of a model to an original. In steps, Achtenhagen thus considers (1) reality, (2) a model of reality, (3) a didactic model of the model under a didactic perspective (goals and contents), (4) the choice of instructional strategies, and (5) evaluation.

Another example of an ID-model that takes the World of Work as a starting point can be found in Michael Spector's contribution, 'Philosophical implications for the design of instruction'. His focus is on the design of instruction for learning in and about complex systems. Such learning typically occurs in the context of working with others to solve relatively complicated problems. His MFL framework (Model Facilitated Learning) combines work on cognitive apprenticeship, cognitive complexity, collaborative learning, problem-based learning and situated learning. According to MFL, learning should be situated in a real or synthetic, complex, dynamic environment and there should be opportunities for the elaboration of a learner's models and experiences with other similarly situated learners. In particular, MFL suggests that there must be a number of phases in learning (cf., Piaget, 1970), with a graduated progression from concrete experiences towards more abstract reasoning and hypothetical problem solving.

It is interesting to note that Spector's preference for this situated approach, fitting our World of Work, is mainly pragmatic. It is simply argued to be the most fruitful and promising approach for dealing with complex learning, or, instructional design for learning in and about complex systems. Its philosophical, ontological roots are traced back to a *holistic* perspective, which dominated classical Greek philosophy, then became less popular, but re-emerged in the last half of the 20th century (e.g., in the work of Forrester, 1961, on system dynamics). But Spector also seems to agree that other approaches may be useful, or even necessary to deal with targeted learning outcomes other than complex learning. He describes two other ontological perspectives. The first is the *analytic* perspective that closely resembles our World of Knowledge. This approach can be traced back to Descartes' *Discourse on Method* (1960), in which the process of dividing and subdividing a problem until small, immediately understandable parts were found, is described. The second is the *synthetic* perspective that closely resembles our World of Learning. Here, the focus is on what people do in the world and on an ontology of action. Activity Theory (Nardi, 1996) stresses, for example, that activities quite often involve other persons and various artifacts and that particular activities require a synthetic process (or authoring process) directed at the development of particular kinds of learning supports and facilitation.

Spector concludes that the implications of the three ontological perspectives are poorly, not fully, understood and are not applied consistently. Furthermore, his analysis seems to imply that taking one particular perspective, or working within one particular World of ID, may be fruitful for a particular category of targeted learning outcomes, but not for other categories of learning outcomes. Based on the divergent approaches on the same domain the authors argue that future work in the practical, eclectic field of ID should aim at bringing the Three Worlds of ID together. It might be impossible to reach a true reconciliation of the three ontological perspectives that underlie the worlds, but the attempt itself may take the field of ID one step further. What the community of instructional designers need are bridges over the troubled waters between the Three Worlds.

Future directions: Bridges over troubled water

Norbert Seel's 'Epistemology, situated cognition, and mental models: 'Like a bridge over troubled water' ' is the only contribution in this Special Issue that does not nicely fit within one of the three worlds. It introduces the concept of 'mental models' as a way of building a bridge between cognitive science and the field of instructional design. Seel describes mental models as cognitive artifacts or inventions of the human mind that represent, organize and restructure the learners' knowledge base in such a way that even complex phenomena of the – observable or imagined – world become plausible. The reported exploratory study makes clear that mental models play a central role in learning. On the one hand, learners dynamically construct mental models on the basis of their generic world knowledge and the particular learning task they are facing. On the other hand, effective instruction (i.e., presenting a conceptual model in the beginning of instruction) positively affects the stability of mental models, or, more accurately, the successful reconstruction of mental models during learning.

Simply speaking, the claim of a central role for mental models in ID means that such an approach does not fit the World of Knowledge since it rejects a taxonomy of learning outcomes as a starting point for design. Instead, mental models are seen as meaningful wholes. It does not fit the World of Learning because there is no clear focus on particular learning processes. Instead, the ad-hoc nature of mental models is emphasized. And finally, it does not fit the World of Work because realistic task performance is not a starting point for design. Learners may indeed construct mental models to reflect such performance, but the models do not simply represent or reproduce it. At the same time, it might be argued that mental models offer a theoretical construct that may help to combine the three Worlds of ID. Figure 3 shows the necessary three bridges over troubled water.

First, mental models may provide a bridge between the World of Work and the World of Knowledge. Mental models are meaningful *wholes* that can be seen as qualitative mental representations, which are developed by learners on the basis of generic world and domain knowledge with the aim

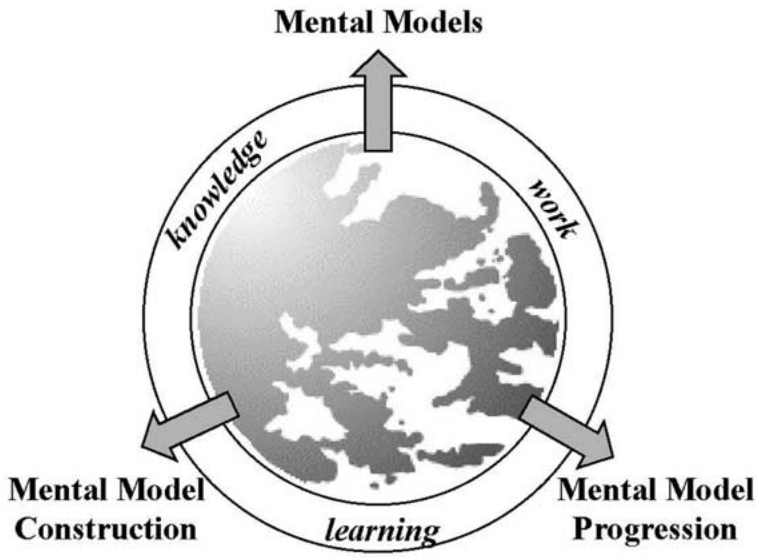

Figure 3. Bridges over troubled water: How mental models link the three worlds of ID.

of solving problems or acquiring competence in a specific domain. Mental models represent the whole body of knowledge that enables the performance of a professional skill in a particular situation and thus fit well with the World of Work. From a psychological point of view, mental model approaches may lack the simplicity of systems based on knowledge objects (cf. Merrill) or rules (cf. Scandura), but from an instructional point of view it is worthwhile to think in terms of mental models because they provide a higher level of reasoning about the knowledge underlying the performance of complex tasks. For instance, mental models may be used to make instructional sequencing decisions as will be described below. In addition, mental models are liable to further analysis as in the World of Knowledge. It may be argued, for example, that people have a set of highly interrelated knowledge structures for representing the form, structure, and function of various objects, events and activities. They also have a set of procedures and heuristics for reasoning about these objects, events, and activities and for generating purposeful behaviors. In principle, mental models might be analyzed in such knowledge structures, procedures and heuristics if this is necessary for the instructional design process (e.g., Anderson, 1988; Van Merriënboer, 1997). However, the analysis of mental models is in a relatively immature state compared to the analysis of distinct skills and declarative knowledge structures. The development of representational formats for mental models and associated analysis techniques is seen as an important goal for future research.

Second, mental models may provide a bridge between the World of Knowledge and the World of Learning. The key concept here is *mental model construction*. The question is how learners construct their mental models, or, how they reconstruct mental models when their expertise develops. It is yet unclear how learning and constructive processes with regard to mental models can be best described. Often, authors describe mental model construction in a terminology that originated from the World of Knowledge. For instance, Seel refers to accretion, restructuring and tuning, processes that are rooted in the schema theory of Rumelhart and Norman (1978). Van Merriënboer (1997) describes mental model construction in terms of the well-known distinction between automation and schema construction. But the problem is that these learning processes are coupled to knowledge elements (rules and schemata) at a level of abstraction that is far below that of mental models as meaningful wholes. Future research should aim at a description of constructive processes for mental models that are at a more appropriate level. Possibly, research on conceptual change and on the transitions from naive mental models to more effective mental models with increasing expertise in a domain (e.g., Snow, 1990) may provide useful input.

Third, mental models may provide a bridge between the World of Learning and the World of Work. The key concept here is *mental model progression*, an approach to instructional sequencing in which to-be-presented learning tasks are based on increasingly more elaborated versions of to-be-constructed mental models (e.g., Spector, this issue; White & Frederiksen, 1990). A progression should start with a model that contains the ideas that are most simple, representative, fundamental, and concrete. However, the model must be powerful enough to enable the formulation of non-trivial tasks that learners may work on. Then, subsequent models add complexity or detail to a part or aspect of the former models and become elaborations of them – or they provide alternative perspectives on solving problems in the domain. This process continues until a level of elaboration and a set of mental models offering different perspectives is reached that may underlie the required exit behavior (Van Merriënboer, 1997). In a sense, this process is complementary to mental model construction because knowledge about mental model construction is translated into a series of models that underlie professional task performance in different phases of expertise development. Research should answer the question how models of expertise can be made most useful for instructional purposes. This is an important process of didactic specification, which Achtenhagen (this issue) referred to as ‘modeling the model’.

Concluding, it has been argued that mental models might be helpful to build bridges between the three worlds of ID. But the main point is that future research should aim at the development of a common language, an instrument that allows for better communication between the three worlds. Whether mental models or other theoretical constructs are the most fruitful element of such a common language needs to be seen. At the very least, the search for a common language itself will help us to take multiple perspectives on the field of Instructional Design and further improve our insights about how to help people learn better. And that is what instructional theory is all about.

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