Implications of Constructivism for Computer-Based Learning

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Abstract

Constructivism has gained popularity recently, but it is not a completely new learning paradigm. Much of the work within Information Systems Science (IS) and especially within e-learning use Constructivism as a reference 'discipline' (explicitly or implicitly) but few of the works done within IS discusses thoroughly what are the basic assumptions and implications of Constructivism. As a result, the technology has driven the applications, with theory only vaguely or superficially applied. Constructivism provides one theoretical approach to the use of computer-based systems, and, as such, deserves careful consideration. IS researchers – as IS is a transdisciplinary field - should seek to do research which is good in terms of other disciplines and we need to go back to the original texts in the reference discipline to gain genuine appreciation of the arguments being proposed. This is also the aim of this paper.

Keywords

Constructivism, Learning theories, Computer-based learning environments

1. Introduction

The idea for this paper arose from the authors' observation that in the field of educational sciences there is a view of learning which is increasingly cited within Information Systems Science (IS). Jonassen and Land (2000) note that during the 1990's we have witnessed a convergence of learning theories never before encountered. These contemporary learning theories are based on substantially different ontologies and epistemologies than what used to be the traditional objectivist foundations for instructional design. Here we will introduce a relatively new view of learning - Constructivism. We are interested in Constructivism because it seems to give a lot of suggestions on how to construct computer-based/virtual/e-learning environments.

Bednar, Cunningham, Duffy, and Perry (1992) argue that in the field of instructional systems technology it has been appropriate to select principles and techniques from the many theoretical perspectives, choosing those we like best and ending up with a design technology based on no single theoretical base. Thus, concepts and strategies are abstracted out of their theoretical framework, placed within a practitioner's framework, and grouped based on their relevance to a particular instructional design task. However, effective instructional design emerges from the deliberate application of some particular theory of learning.

But why do we want to introduce Constructivism for an IS audience? Jones (1997) argues that we need to have a broad understanding of social processes, a subject in which relatively few IS academics would consider themselves to be experts. There is a risk of poor quality research if people struggle to operate in areas in which they are inadequately qualified. In general, this, we feel, puts forward a demand to learn from the other disciplines overlapping with the research areas and targets of IS.

Because IS is a multidisciplinary field, IS researchers need to engage with many disciplines, rather than assume that the department within which they are located defines the boundaries of the subject. IS researchers should seek to do research which is good in terms of other disciplines. A practical consequence of this is the need for IS researchers **to go back to the original texts in the reference discipline** to gain genuine appreciation of the arguments being proposed (Jones, 1997).

Further support for the need of this paper can be found by browsing through the work dealing with educational technology within IS. This work often cites the main ideas of Constructivism, but seldom presents a proper representation of the learning view, leaving it open whether the authors really have digested the presumptions they are building their proposals on. E.g. when reading through the papers in ECIS 2002 proceedings, the papers in the *Virtual Learning and Teaching* track discuss collaborative technologies, distance and on-line learning, but most of them have either no or only very superficial reference to the original educational texts. From the eleven papers in the track the ones building their work directly on some of the original sources are Bolz (2002), Renzi and Klobas (2002), and Neville, Adam, and McCormack (2002).

Actually IS writers often refer to other IS writers, who may have studied the original works only limitedly. See, e.g. the excellent paper from Leidner and Jarvenpaa (1995) which discusses the technological perspective of using IT in management school education, but bases the description of Constructivism on four references only; still this paper is one that seems to form the basic constructivistic source material for many IS researchers.

2. Background

Today's ways of understanding learning can be appreciated only against the historical background of thoughts on human learning and in relation to one another. All the theories still remain a vital part of the way we think. Unlike many other scientific theories, learning theories are generally not replaced by superior ones, but rather incorporated into subsequent theories. The most influential theories have been **Behaviorism** and **Cognitive Psychology** (Lehtinen & Kuusinen, 2001).

For **Constructivism**, the basic forms of interpreting human thinking are shaped in the work of Piaget. One of the principles in Piaget's thinking was that cognitive constructions develop through action. Processes of the mind develop from action which is originally concrete, but they can also later develop through internal mental processes without direct connection to the external action.

One way of looking at different views on learning is described by Duffy and Jonassen (1992). **The objectivist tradition** acknowledges that people have different understandings based on differing experiences. However, the impact of prior experience and human interpretation is seen as leading to partial understandings and biased understandings. The goal here is to strive for the complete and correct understanding. Knowledge is believed to exist independently of instruction and there is no need to look at the instructional activities to see what is learned. The objectivist epistemology underlies Behaviorism and much of cognitive psychology. Also Constructivism holds that there is a

real world that we experience. However, there are many ways to structure the world, and there are many meanings or perspectives for any event or concept. Thus, there is not a correct meaning that we are striving for. Jonassen (1992) notes that objectivism and Constructivism are often described as polar extremes of a continuum in order to contrast their assumptions. Jonassen, however, states that most theorists assume positions that fall somewhere between the extremes.

3. The Formation of Constructivism

Lave and Wenger (1991) do not directly discuss Constructivism, but their text is one that is very often referred to in constructivist literature. They emphasize that learning as internalization is too easily construed as an unproblematic process of absorbing the given, as a matter of transmission and assimilation. Lave and Wenger's work concerns the concept of **apprenticeship** and the theory of **situated learning**. According to their perspective there is no activity that is not also situated. They emphasize the comprehensive understanding involving the whole person rather than receiving a body of factual knowledge about the world; activity in and with the world; the view that agent, activity, and the whole mutually constitute each other. They state that even the so-called general knowledge only has power in specific circumstances, because abstract representations (generality) are meaningless unless they can be made specific to the situation at hand. On the other hand, the world carries its own structure so that specificity always implies generality.

The second shift in perspective Lave and Wenger (1991) have is to explore learning as **legitimate peripheral participation**, which means that a learner is always located in the social world, and changing locations and perspectives are part of actors' learning trajectories, developing identities, and forms of membership. Peripherality is a positive term, suggesting an opening, a way of gaining access to sources for understanding through growing involvement. Lave and Wenger note that legitimate peripheral participation is not an educational form, but an analytical viewpoint on learning, a way of understanding learning. In their concept of learning, the learner is a newcomer who changes knowledge, skill, and discourse, and becomes an old-timer. This is a process of developing identity and the learner transforms into a member of a community of practice. Knowing is inherent in the growth and transformation of identities and it is located in relations among practitioners, their practice, the artifacts of that practice, and the social organization of communities of practice.

Duffy and Jonassen (1992) argue that instruction should not focus on transmitting plans to the learner but rather on developing the skills of the learner to construct (and reconstruct) plans in response to situational demands and opportunities. Thus, instruction should provide contexts and assistance that will aid the individual in making sense of the environment as it is encountered. Plans must be constructed, tested, and revised as a function of the particular encounters in the environment. Learning environments based on the objectivist view of learning are problematic because (p. 5): *Computer models of mind rely on a formalization of knowledge. Experiences must be represented in some propositional form. However, any propositionalization is simply one representation of that prior experience. The individual, but not the computer or the computer model of mind, can reconceptualize, reconstruct, and repropositionalize that experience in many different ways. It is the storage of experiences (unformalized background) that the computer systems and models cannot achieve…*

Spiro, Feltovich, Jacobson and Coulson (1991) interpretation of Constructivism is complex. They start by taking an accepted cognitive principle that understanding involves going beyond the

presented information. Comprehension involves the construction of meaning: the information contained in the text must be combined with information outside of the text – including the prior knowledge of the learner – to form a complete representation of the text's meaning. Secondly, emphasis must be shifted from the retrieval of intact knowledge structures to support the construction of new understandings. Learners should be able to bring together from various knowledge sources an appropriate ensemble of information suited to the particular problem-solving needs of the situation at hand - instead of retrieving from memory a previously packaged prescription for how to think and act. This kind of Constructivism is doubly constructive: (a) understandings are constructed by using prior knowledge to go beyond the information given; and (b) the prior knowledge that is brought to bear on is itself constructed, rather than retrieved intact from memory, on a case-by-case basis.

Constructivism was originally based on the belief that technology based learning could convey information and understanding more effectively than teachers. By now it has been realized that you cannot convey understanding; that can only be constructed by learners. Jonassen and Land (2000) list several conceptions of learning that share many beliefs and assumptions. These views are based on the belief that learning is neither a transmissive nor a submissive process, but rather a willful, intentional, active, conscious, constructive practice that includes reciprocal intention-action-reflection activities (figure 1). The views mentioned are socially shared cognition, situated learning, everyday cognition and everyday reasoning, activity theory, ecological psychology, distributed cognitions, and case-based reasoning. They are based on a similar ontology, epistemology, and phenomenology.

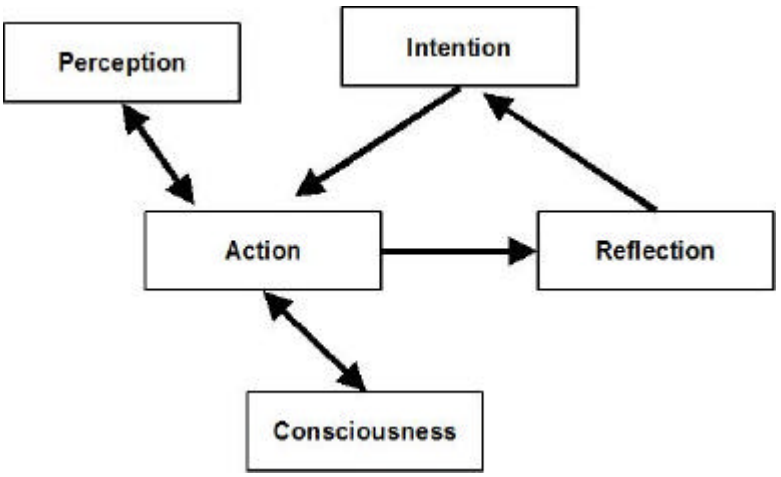

Figure 1: Learning as intention-action-reflection (Jonassen & Land, 2000).

Besides of the process, the different views have in common the assumption that we are obligated to consider not only the performances of the learners, but also the sociocultural and sociohistorical setting in which the performance occurs and tools and mediation systems that learners use to make meaning (figure 2).

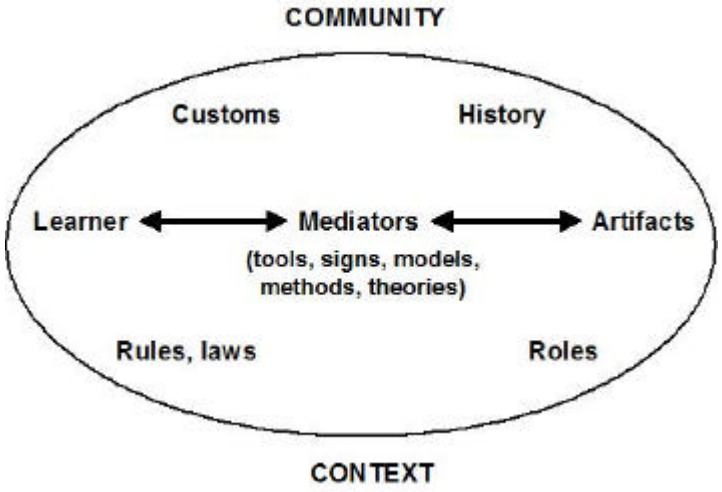

Figure 2: Learning in context (Jonassen & Land, 2000).

4. Implications for Designing Learning Environments

Traditional Computer Aided Instruction (CAI) has emphasized a very systematic approach to the design of learning environments. This approach is called Instructional Systems Design (ISD). Boyle (1997, p. 68) notes that ISD has developed a clear method for developing learning environments: *…the systematic analysis of task requirements will map onto the steps the learner will have to go through to acquire the knowledge. This analysis will normally yield a hierarchical classification where goals are broken down into sub-goals, and the content required to achieve the lowest sub-goals is specified.*

Bednar et al. (1992) have quite an extreme view of how Constructivism differs from the old design principles of traditional behavior theory. They argue that effective sequencing or rigorous external control of instructional events simply precludes constructive activity and the possibility of developing alternative perspectives. The aim should be to facilitate situating cognition in **real-world contexts**, teaching through cognitive apprenticeship, and construction of multiple perspectives. By real-world contexts Bednar et al. (1992) mean that:

The task is not isolated but rather a part of a larger context. We should create projects or environments that capture a larger context in which the problems are relevant.

The reason for solving the problems must be authentic to the context in which the learning is to be applied.

The environmental context is critical. Learning always takes place in a context and the context forms an inexorable link with the knowledge embedded within it. Thus, an abstract, simplified environment is not just quantitatively different from the real-world environment but it is also **qualitatively different**. Authentic learning environments may be expected to vary in complexity with the expertise of the learner.

The last point receives support from the *Cognitive Flexibility Theory*. Spiro et al. (1991), who summarize their own research, note that a common thread running through the deficiencies in learning is oversimplification. Compartmentalization of knowledge components works as an effective strategy in well-structured domains, but blocks effective learning in more intertwined, ill-structured domains (where each example of knowledge application typically involves the simultaneous

interactive involvement of multiple, wide-application conceptual structures) which require high degrees of knowledge interconnectedness. Ill-structured domains require multiple representations for full coverage. Spiro et al. have found that a single analogy may help at early stages of learning, but actually interferes with more advanced treatments of the same concept later on, when the knowledge domain is more intertwined and ill-structured requiring high degrees of knowledge interconnectedness.

Spiro et al. (1991) argue that **revisiting the same material**, at different times, in rearranged contexts, for different purposes and **from different conceptual perspectives** is essential for attaining the goals of advanced knowledge acquisition. Content must be covered more than once for full understanding because of psychological demands resulting from the complexity of case and concept entities in ill-structured domains. This should be combined with the importance of contextually induced variability and the need for multiple knowledge representations and multiple interconnectedness of knowledge components. Re-examining a case in the context of comparison with a case different from the comparison context will lead to new insights.

Also the concept of *generative learning environments* has been suggested to emphasize the importance of anchoring instruction in meaningful, problem-solving contexts that make it possible to simulate the advantages of apprenticeship learning (Cognition and Technology Group at Vanderbilt University, 1992, p. 78): *A major goal of this approach is to create shared environments that permit sustained exploration by students and teachers and enable them to understand the kinds of problems and opportunities that experts in various areas encounter and the knowledge that these experts use as tools*. The research group of Vanderbilt suggests the following design principles:

The problem situation information is displayed in the form of **dynamic images**: the problems to be communicated can be much more complex and interconnected than in written format and the students can form rich mental models more easily.

Narrative format to represent information (meaningful context for problem solving).

Generative learning format. Learners are allowed to determine themselves what the outcome of the exercise will be (motivation of the learners).

Embedded data design: all the data needed to solve the problems are to be embedded within the narrative. The problems are not explicitly formulated in the environment, but incidentally presented in the story.

Problem complexity. Students cannot be expected to learn to deal with complexity unless they have an opportunity to do so.

Pairs of related adventures. Concepts that are acquired in only one context tend to be welded to that context and hence are not likely to be spontaneously accessed and used in new settings (as Spiro et al., 1992).

Links across the curriculum (to introduce topics from other subject matters).

Jonassen (1992) has described three stages of knowledge acquisition (figure 3): introductory (learners have very little directly transferable prior knowledge), advanced (needed to solve complex, domain- or context-dependent problems), and expert (experts have more internally coherent yet more richly interconnected knowledge structures). He argues that Constructivistic learning environments are most effective for the stage of advanced knowledge acquisition. He also first states

that introductory knowledge acquisition is best supported by more objectivistic approaches, but after some thinking about the Piagetian and Vygotskian heritage notes that younger, novice learners are probably the most constructivistic learners. As the learners acquire more knowledge a transition to constructivistic approaches is needed to represent complexity and ill-structuredness as learners acquire more knowledge. Experts need very little instructional support.

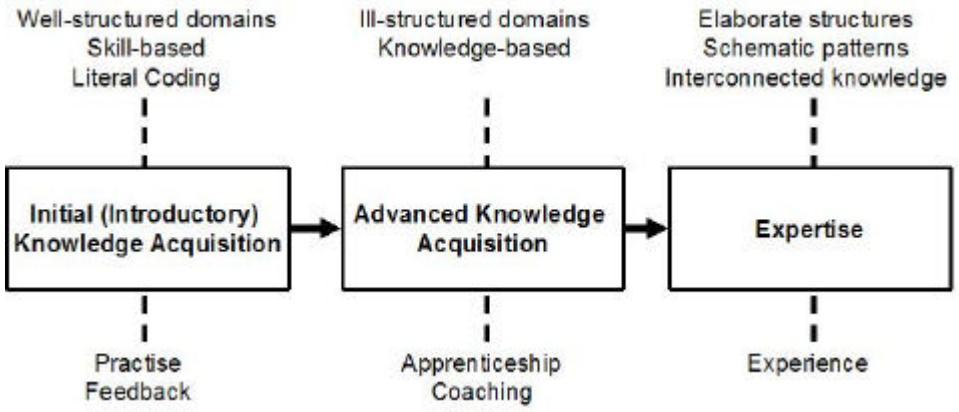

Figure 3: Three stages of knowledge acquisition (Jonassen, 1992).

Duffy and Cunningham (1996) present and justify their version of Constructivism in a paper often referred to in the field of education:

- All knowledge is constructed; all learning is a process of construction. Learning is a matter of changes in one's relation to the culture to which one is connected.
- Many world views can be constructed; hence there will be multiple perspectives. The engagement with others creates the awareness of multiple perspectives.
- Knowledge is context dependent, so learning should occur in contexts to which it is relevant. However, the physical character of the environment is relevant only to the extent it impacts the character of the "thinking" and skill requirements.
- Learning is mediated by tools and signs. All distinctly human instances of learning are constructions situated within a context that employs some form of mediational means, tools, and/or signs.
- Learning is an inherently social-dialogical activity. Knowledge, and thereby learning, is a social, communicative, and discursive process, inexorably grounded in talk. The way in which an individual (a student) comes to manifest the effective behavior of a community is to speak with the voice of that community.
- Learners are distributed, multidimensional participants in a sociocultural process. A distributed concept of self shifts the activity of learning to the connections one has with communities, to the patterns of participation, and away from efficient internalization of knowledge. As Lave and Wenger (1991) state that learning is not the lonely act of an individual, but a matter of being initiated into the practices of a community, moving from legitimate peripheral participation to centripetal participation in the actions of a learning community.

- Knowing how we know is the ultimate human accomplishment. We are generally unaware of the beliefs we have adopted or created to live and teach by, but raising them to awareness can have salutary effects.

Duffy and Cunningham (1996) describe problem-based learning (PBL), which they feel exemplifies the constructivist theory. The focus should be on developing the skills related to solving the problem as well as other problems like it. Skills are developed through working on the problem, i.e. through authentic activity. It is impossible to describe what is learned in terms of the activity alone or in terms of the content alone (p. 190): *Rather, it is the activity in relation to the content that defines learning: the ability to think critically in that content domain, to collaborate with peers and use them to test ideas about issues, and the ability to locate information related to the issues and bring it to bear on the diagnosis*. The teacher does not teach students what they should do/know and when they should do/know it. Rather, the teacher supports the students in developing their critical thinking skills, self-directed learning skills, and content knowledge in relation to the problem. The key issues that one should go through in designing PBL instruction are the following:

Task analysis: What must be learned? Combine identification of the key concepts, procedures, etc., with an analysis of the professional use of those concepts. But this does not involve the analysis of that key information into underlying learning requirements. What must be learned includes not only the information in the content domain but also metacognitive, collaborative, and other skills necessary for participating in authentic activity.

Problem generation: This determines what the students must learn. The two principles to follow are: (1) The problems must raise the concepts and principles relevant to the content domain. (2) The problem must be "real". Real problems tend to engage learners more; there is a larger context of familiarity with the problem.

The learning sequence: The learning cycles go through two types of learning activities: collaborative problem analysis and self-directed learning. For example, the whole class might first work to identify learning issues in the content area and then small groups assume responsibility for particular issues. They develop expertise on those issues and then share that expertise in large-group problem solving. Throughout the sessions the facilitator models high-order thinking by asking questions that probe knowledge.

Today, the basic principles of Constructivism seem to be more or less established: Technologies can support learning if they are used as tools that help learners to think.

Applying Constructivism in Computerized Environments

A vast majority of the literature about e-learning or virtual education seems to be dealing with how to:

transform the learning material into an online format,

arrange distance communication between the students and the teacher or between the students, or

use discussion platforms, which are supposed to enhance student participation.

Mainly this is all about just changing the original learning content to an alternative format. What is lacking is the discussion about whether the new technologies can offer totally new ways of educating the students. Many skeptics believe that replacing the classroom-based education with the Internet-

based education leads to substandard education. To take one example (Noble, 1998): Last but not least, behind this effort are the ubiquitous technozealots who simply view computers as the panacea for everything, because they like to play with them. With the avid encouragement of their private sector and university patrons, they forge ahead, without support for their pedagogical claims about the alleged enhancement of education, without any real evidence of productivity improvement, and without any effective demand from either students or teachers.

Others (e.g. Neumann, 1998) state that to be successful, online instruction requires even more organization and forethought in creating courses than otherwise, since there may be only limited interactions with students, and it is difficult to anticipate all possible options. Thoughtful planning and carefully debugged instructions are essential to make the experience more fulfilling for the students.

Verma and Parikh (2001) note that there are several valid problems with the current course web sites:

Web sites are passive and they lack interactivity, which is crucial in many learning activities such as group discussion, case study analysis, class discussion, asking questions and immediately receiving answers and instructor feedback.

Current Internet technologies do not provide as rich a communication medium as face-to-face meetings in real classrooms provide. E.g. video conferencing demands high bandwidth and is good only for one to one communications.

With web based course material, the instructor is never sure whether the critical, time-sensitive material information is reviewed by all the students. In addition, there is no feedback loop.

For us these descriptions hint that the principles of Constructivism have not been implemented properly. However, available web-based, networked technologies offer opportunities for creating and sustaining collaborative, reflective learning experiences for a distributed student body (Ruhleder & Twidale, 2000). Morgan (2001) describes third generation e-learning (the generation we should be aiming at as soon as possible) as Internet based learning systems that build on a "learner in control" philosophy while incorporating high band-width learning tools and supports such as complex simulations, virtual classrooms and other forms of “online“ collaboration.

So, what are constructivist learning environments (CLEs)? Jonassen, Peck and Wilson (1999) find this question to be a difficult one to answer. They state that CLEs are technology-based environments, in which students explore, experiment, construct, converse, and reflect on what they are doing, so that they learn from their experiences. Learners are presented with **a complex and relevant problem**, project, or experience that they accept or reject as **a challenge**. Then the CLE provides them with the tools and resources that they need to understand the problem and to solve it (or attempt to solve it). CLEs are not necessarily dependent on technology, they are often supported by computers. Jonassen et al. describe the components needed in successful CLEs:

Problem/project space: learners are presented with an interesting, relevant, and engaging problem to solve. The problem must not be overly defined, it should be complex and somewhat ill-defined (learners are let to determine some aspects to create ownership) and based on a real-world situation. It is important to describe the context of the problem, because that, to a large extent, defines the nature of the problem. The problem presentation has to be interesting, appealing, and engaging (to achieve buy-in from the learners). Its purpose is to simulate the problem in the context in which it is normally and naturally encountered. The problem space also has to provide an

opportunity to manipulate or experiment with the problem. There will be no ownership of the problem unless the learners know that they can affect the problem situation in a meaningful way.

Related cases: When expecting the learners to solve problems, it is important for the learning environment to provide access to a set of related experiences on which the learners can draw. This supports learning by scaffolding memory and by representing complexity (multiple perspectives). The richer the experience, the richer the memories of the experience. By presenting related cases, the learners are provided with a set of experiences to compare to the current problem.

Information resources: Providing learners with the information they need helps them make meaning when it is provided in a timely manner.

Cognitive (knowledge-construction) tools: Complexity calls on skills that learners possibly do not posses. If this is the case, then cognitive tools that support the learners' abilities to perform those tasks are needed. These can provide help in constructing and representing what the learners know (like visualization tools).

Conversation (knowledge-negotiation) tools, to support collaboration.

Social/contextual support: The weakest part of the process of instructional design has been the implementation of the technology. This is because the innovators fail to consider environmental and contextual factors, like physical environment or social, organizational, and cultural aspects of the environment.

Conclusions

Our aim in this paper has been to clarify the concepts, beliefs, and understandings related to Constructivism. We hope this work will make a small contribution in making the learning view more understandable for the IS community. Constructivism is not a coherent learning theory. It is more a set of principles that can be applied especially when designing computer-based instructions. Not all the advocates of Constructivism share the same view of these principles, and how strictly these principles are applied varies.

Merrill (1992, p. 111), when comparing Constructivism and Instructional Transaction Theory, has stated: *Who is right? In the eternal scheme of things, none of us understands very much about how humans learn, how the mind functions. What is mind? What is knowledge? Both sets of assumptions may be wrong together. They are undoubtedly both incomplete. So, how does one choose?* Merrill states that as compelling as the arguments of the constructivists may be, there is no empirical evidence in support of their assumptions.

This probably applies to all views of learning.

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