6 Constructivism

When It's the Wrong Idea and When It's the Only Idea*

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Overview: Constructivist Approaches as Necessary in Ill-Structured Domains and Desirable for Deep Learning on the Web

Constructivist approaches to learning and instruction have been roundly criticized in several prominently placed articles in recent years (e.g., Mayer, 2004; Kirschner, Sweller, & Clark, 2006). A key to the power of the critiques has been the predominance of empirical findings indicating the greater effectiveness of highly guided instruction when compared to constructivist approaches that have a relative lack of direct instructional guidance. It is not a coincidence that these empirical findings have come almost exclusively from well-structured domains within mathematics and science and a few outside those areas (e.g., more orderly aspects of reading development related to the graphophonemic code). We have no objection to the argument that highly guided learning and direct instruction can be maximally effective in such domains, where by their very nature it is possible to determine what information "fully explains the concepts and procedures that students are required to learn" (Kirschner et al., 2006, p. 75).

The argument of this chapter is a simple one: the success of direct instructional guidance approaches in well-structured domains (WSDs) cannot extend to ill-structured domains (ISDs), *in principle*, because of the very nature of those domains. That which would be directly instructed and explicitly guided *does not exist* in ill-structured domains – hence the claim that it is *not* a coincidence that direct instructional guidance approaches lack a corpus of supporting data in ISDs like they have in WSDs. Given that the debate between these approaches is unsettled on empirical grounds for ISDs, this chapter aims to provide some conceptual clarification of key issues of learning and instruction in such domains. The hope is that such clarification would contribute toward forming a basis for empirical work that would directly address the debated issues of this volume.

The argument will be developed by first discussing the nature of ISDs and the kinds of learning and instruction that that nature would seem to exclude by

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definition. Then we will present quotes from papers by direct instructional guidance advocates in order to make their goals and recommendations explicit. It will be shown that those explicitly stated goals could not be achieved given the very nature of learning in ISDs. That is, what *makes* a domain ill structured is the absence of the very features that are supposed to be directly instructed and supported. Further, empirical evidence will be cited for the hazards of treating ISDs as if they were WSDs in the kinds of guidance and support provided. The differing nature of guidance and support in a constructivist framework developed for learning and instruction in ISDs is briefly addressed. In the penultimate section, an argument is presented for the Web as an ideal environment for deep learning in ISDs, but one that requires relatively open exploration unfettered by direct instructional intervention for that potential to be achieved. In the final section, we make the claim that treating ISDs as if they were well-structured is no longer just an academic argument with implications for such things as test scores (as important as the latter may be), but rather has potentially significant societal consequences.

The Problem of Ill-Structured Domains

We will argue that direct instructional guidance approaches are *necessarily* "misguided"—in several ways—in ill-structured domains. Let us begin, then, with a discussion of ISDs.

Wittgenstein (1953) famously provided the following example of an ill-structured concept. He analyzed the concept of games and demonstrated that for the set of all consensually accepted instances of games, there was no feature common to all. Any attempt to identify the necessary and sufficient conditions for something to be called a game fails. This is true of any ill-structured concept and, by extension and to an even greater extent (and with profound implications for knowledge application), for ill-structured *domains* (or, more precisely, those *parts* of domains that are ill structured). Ill-structured domains are characterized by being indeterminate, inexact, noncodifiable, nonalgorithmic, nonroutinizable, imperfectly predictable, nondecomposable into additive elements, and, in various ways, disorderly (Spiro, Vispoel, Schmitz, Samarapungavan, & Boerger, 1987; Spiro, Collins, & Ramchandran, 2007). An important feature of ISDs is that one cannot have pre-packaged prescriptions in long-term memory for how knowledge in those domains is to be applied across any reasonably large range of situations. This is because *irregularity* is a crucial feature of ISDs. That is, the circumstances for knowledge application in ISDs are characterized by considerable variability from one instance to another, and thus pre-specifiability of the conditions for knowledge use is not possible.

Ill-structuredness should not be confused with *complexity*. Complexity alone does not connote ill-structuredness. In fact, many well-structured domains demonstrate complexity. A key feature in separating well-structured complexity from ill-structured, as we have said, is the regularity (or lack thereof) demonstrated by same-named concepts and phenomena across instances. For example, the physiology of force production by muscle fibers is complex. Many hundreds of thousands of fibers perform processes involving intricate anatomical mechanisms (e.g., the sliding and ratcheting of actin and myosin filaments) and even more intricate interactions of calcium ion pumps in the activation (recruitment) of muscle cells. However, given that each fiber of a given sort (e.g., skeletal muscle) produces force in the *same* (complex) way, there is *regularity* in the application of this concept (Coulson, Feltovich, & Spiro, 1989; Feltovich, Spiro, & Coulson, 1989). As such, the domain is not ill structured, and is instead one of "well-structured complexity."

Consider, on the other hand, concepts such as core democratic values in social studies. Ideas like "justice" or "the common good" are ill structured because they are complex and because instances of their application vary considerably in *how* they are understood (Spiro et al., 2007). Because of this irregularity, definitions and explicit guidance work for too small a set of possible applications and miss too many legitimate ones, while at the same time seducing the learner to rely on the explicit guidance.

Examples of ill-structured domains include the obvious ones: social studies, humanities, and the arts. But many aspects of more "scientific" domains have an ill-structured quality (e.g., most "macro" concepts of evolutionary biology, such as "adaptation"; Mayr, 1988). Further, all areas of knowledge application in unconstrained, real-world situations tend to have substantial aspects of ill-structuredness. Think of the difference between experimental design as sequentially and incrementally taught in a statistics course versus decision-making when trying to design a test of a theory-driven hypothesis "in the wild." Similarly, consider the difference between basic biomedical science and clinical practice, or between engineering practice and its underlying physical and mathematical principles. All professional domains present challenges of ill-structuredness. Whereas biomedical cognition clearly has some well-structured, basic science components in anatomy and physiology, as well as in many aspects of diagnosis, treatment/management decisions are affected by so many contextual factors that they are inevitably characterized by considerable indeterminateness. Such decisions depend on myriad unanticipatable interactions of those contextual variables, each of which can take on many values—for example, the severity of patients' primary conditions; the presence or absence of secondary conditions; individual preferences that affect trade-offs between, say, pain reduction and clarity of thought; effects of treatments on differing job-performance requirements; and many, many others.

That professional domains are ill structured becomes especially clear when one considers teaching (e.g., Lampert, 2001; Palincsar et al., 2007; Shulman, 1992; Sykes & Bird, 1992). A prospective teacher can take a dozen courses on "methods," but once in the field it becomes clear that "it's not that simple," "it depends," "it's not either–or" are watchwords of practice. For example, how does one teach the appropriate situation-specific application of a ubiquitous teaching concept like "scaffolding" (Palincsar et al., 2007)? Not by providing a pre-specified set of rules for the application of the concept. That is not possible, and any candidate rules that help in some situations will mislead in others. The way such a concept is learned for application is through the accumulation of considerable experience, the exposure to many examples, and an appreciation for multiple interacting contextual features (Palincsar et al., 2007). That is the reason for the oft-cited "10-year rule" for the attainment of expertise in complex domains (Ericsson, Charness, Hoffman, & Feltovich, 2006; see also Sternberg, 2001). This leads to the ability to detect patterns of *family resemblance* in much the same way as Wittgenstein illustrated for the application of the concept of games. Absent defining conditions for knowledge use and generalizable procedures for knowledge application, constructivist approaches are not just *nice*, they are *necessary*. Yes, the cognitive load of such learning will be high, and support will be required. But that support will have to be different from the kind recommended by Kirschner, Sweller, and Clark (see the treatment of their explicit recommendations in the next section).

Direct Instructional Guidance and the Idea of Full Explanation of Essential Information, Concepts, and Procedures

Kirschner et al. (2006) elegantly demonstrate the appropriateness of direct instructional guidance in well-structured domains. However, as we will see, the very arguments that elucidate best practice for WSDs at the same time demonstrate why direct instructional methods do not apply in ISDs, and indirectly provide insights into why constructivist methods do. In this section we will examine several aspects of the *explicit* direct instructional guidance argument.

It should be noted that this section is built around *quotes* from direct instructional guidance theorists that may be seen as *defining* their position. The quotes are drawn from Kirschner, Sweller, and Clark's very influential piece in *Educational Psychologist*. In relying on these quotes it should be added that it is not always clear in private conversations and public discussions that these authors faithfully adhere to the letter of their published assertions. Further, there is evidence of some movement away from the more extreme stances they have taken (e.g., van Merriënboer & Sweller, 2005, where Cognitive Load Theory is taken in some new directions involving more complex kinds of learning, as has occurred with van Merriënboer & Kirschner's very useful and insightful new book, 2007). It should also be said that these steps have been very much within the same family as their past work on WSDs and thus do not address the special needs of ISDs articulated in this chapter. It is a tribute to them and the quality of their work—and the work of other long-term, careful advocates of direct instructional approaches (e.g., Rosenshine & Stevens, 1986; Rosenshine, 2002)—that their *words* are taken so seriously. So, in this chapter, as the first author did in the AERA debate that is the antecedent of this volume, we will hold them to their literal claims and hold those claims up for scrutiny through the lens of the requirements of learning in ISDs.

Again, the intention is not in any way to devalue the landmark work that has been done in the framework of Sweller's Cognitive Load Theory, say, or by Kirschner in his leading-edge work on complex learning or by direct instructional guidance theorists such as Rosenshine. Rather, we are addressing—and, yes, *rejecting*—the application of central aspects of their *explicit* recommendations when they are applied to ISDs.

Essential Information

Kirschner et al. (2006) discuss the importance of learners "being presented with *essential* information" (p. 75; italics added). In an ill-structured domain, it is the absence of information that could be considered "essential" that makes the domain ill structured. Any sort of Platonist *essentialism* (or, less formally, any attempt to claim essential qualities across situations) is inapplicable in ISDs. If it could be done, they would be WSDs. Present essential information if you can; but if you cannot, do not present a *fiction* that students will take as fact. Information will be treated as essential if presented thus, and will end up interfering with performance in whatever contexts some other calculus of "essentialness" is required.

For example, if a student is in a social studies class and is learning about core democratic values, what is essential about the concept of "justice" for the application of that concept in new contexts? The answer is almost *nothing*. Students who take the Michigan Educational Assessment Program (MEAP) test are required to use two core democratic values in a letter to the editor on a topic they are assigned. They do very poorly at this task and the authors have heard many social studies teachers report that this is a very difficult topic to teach. The reason is that teachers try to give them—and students try to learn—essential qualities of these concepts. However, any purported essential qualities will hit only a small fraction of the contexts in which the concept may be applied (Spiro et al., 2007). Think about all the different ways the concept of "justice" or "the common good" or "liberty" or "equality" are applied, with equal validity, by people with different ideological stances, in the context of different social issues, and so on. When there are so many different ways that a concept may be used, or a concept must be subtly tailored to different contexts, explicitly supporting any one or a small subset of those will provide a crutch that learners and teachers will too readily (over)rely upon.

Lest one think that we are only talking about domains in social studies and humanities, let us reiterate that features of ill-structuredness occur in science domains (for example, the concept of adaptation in biology mentioned earlier), in places where social science concepts intersect with science concepts (e.g., understanding the issue of "sustainability" in climate change discussions), and in *all* professional domains. Consider engineering, for so long thought to be essentially a mathematics- and physics-based discipline, and where it is now widely recognized that, for example, every bridge that is built has its own idiosyncratic "personality" with different span lengths, climatological conditions, terrain features, traffic patterns, etc. The intersection of these features in highly varying combinations across bridge-building makes the reliance on essentialist formulations maladaptively reductive (Petroski, 1992). All professional domains, however much they contain well-structured basic science and mathematics components, become ill structured when those generalizable principles have to be combined and tailored in the context of highly variable cases of application in the real world. Finding "essential information" to present in ISDs is not as easy as studies by direct instructional guidance advocates in math, science, and parts of reading acquisition would lead one to expect (Rosenshine & Stevens, 1986, have noted this).

In general, many more domains have substantial aspects of ill-structuredness than is generally thought. The extent to which ISDs must be dealt with has been *vastly underrated.*

Full Explanation

Direct instructional guidance is partially defined as "providing information that *fully explains* the concepts and procedures that students are required to learn" (Kirschner et al., 2006, p. 75; italics added). In an ill-structured domain, the ideal of full explanation is simply impossible. Otherwise it would be a well-structured domain. Furthermore, providing information advertised as "essential" and "fully explanatory" creates a mind-set in which the learner comes to believe that this *dependent* way of thinking will work, and that the particular information they are provided with really is essential and does fully explain, leaving them nothing more that they have to do. The problem is that they have a lot more that they have to do in an ill-structured domain than whatever was supposedly "fully explained." Going along with the direct instructional guidance way of thinking makes students' and teachers' cognitive tasks easier and thus more attractive. We have referred to the artificial neatening of ill-structured concepts as "seductive reductions," and have empirically demonstrated how they are quickly latched onto to deleterious effect and are very difficult to undo (Feltovich et al., 1989; Feltovich, Coulson, & Spiro, 2001). There is a large body of empirical evidence that early simplifications impede the later acquisition of complexity (Feltovich et al., 1989, 2001; Feltovich, Spiro, & Coulson, 1997; Spiro, Coulson, Feltovich, & Anderson, 1988; Spiro, Feltovich, Coulson, & Anderson, 1989). To take one example, Spiro et al. (1989) provided evidence for nine different ways that the early use of powerful instructional analogies interfered with conceptual mastery in later treatments of the same topic *just* where the source analogy was missing key information or was misleading about the target concept—later learning was *reduced* to the initial explicit guidance and support (even though the limitations of the early models were explicitly mentioned). In the absence of essential information that can be directly instructed and fully explainable procedures, the learner's task in acquisition and application is more difficult, but that difficulty cannot be avoided, only ameliorated. It is a difficulty that must be faced and supported; but the nature of the support that is required cannot be the presentation of essential information and full explanations like that which works so well in direct instructional guidance in well-structured domains.

Direct Instruction on Procedures

Kirschner, Sweller, and Clark also state that "novice learners should be provided with direct instructional guidance on the concepts and procedures required by a particular discipline, and should not be left to discover those procedures by themselves" (2006, p. 75). Yes, known procedures should be directly instructed and maximally guided. But, in an ill-structured domain, repeatable "procedures" do not exist to be provided to the learner. Rather procedures *must* be inferred to fit the situation at hand based on a fresh compilation from existing procedural fragments and other related knowledge.

Of course, this also means there is no *thing* to be "discovered." Here, the advocates of discovery learning are as much on the wrong track in ill-structured domains as the direct instructional guidance theorists. The only thing to be "discovered" is the many vagaries, the subtleties and nuances, the family-resemblance relationships that determine how knowledge from ISDs is legitimately used.

By the way, when we said earlier that direct instructional guidance approaches are generally preferable in WSDs, we did not mean to imply that less-supported constructivist or discovery processes are *never* appropriate in WSDs. For certain concepts and procedures that are central to a domain and for which more active cognitive processing will activate connections that might have been dormant otherwise, the greater cognitive effort associated with discovery learning may be quite fruitful. Thus, we take no stand on the debate between direct instructional guidance and constructivism in WSDs other than to say the direct instructional guidance theorists are probably right that their approach is often the most effective and efficient one given load and time constraints. In the extreme, of course, it is ludicrous to wish for all the acquired knowledge of centuries past to have to be constructed afresh or, worse, *(re-)discovered*. On the other hand, it seems likely that practicing discovery processes in problem solving leads to the acquisition of a useful skill.

The Central Role of Retrieval from Long-Term Memory

Kirschner et al. (2006) say that

> expert problems solvers derive their skill by drawing on the extensive experience stored in their long-term memory and then quickly select and apply the best procedures for solving problems. The fact that these differences [in novice versus expert chunking of familiar situations] can be used to fully explain problem solving skill emphasizes the importance of long-term memory to cognition.
>
> (p. 76)

However, in ill-structured domains, the reliance on chunks, templates, and other pre-packaged prescriptions from long-term memory for how to think and act is the *problem* not the solution. In ISDs, because of the non-overlap of features from case to case (for cases/examples/events/occurrences categorized together), cognitive processing emphasis must shift from retrieval of intact structures to ongoing assemblage of new structures from pieces that were *not* pre-stored together in long-term memory.

For some non-routine problems, reliance on retrieval of templates from an ample library in long-term memory can *interfere* with problem solution. For example, Feltovich et al. (1997) found that expert radiologists who relied on template retrieval (and who had far more of those templates than novices and were able to use them with great success in routine problems) performed more poorly on a non-routine problem than an expert who recognized the need for a novel solution. The latter expert realized that reliance on long-term memory was *limiting* rather than productive (see also Hatano & Inagaki, 1986). To the extent a domain is ill structured, there will be a greater need for creative or emergent problem-solving processes. Overreliance on retrieval of explicit guidance from long-term memory is counter-productive in those situations. The claim that the availability of pre-stored chunks in long-term memory "fully explain problem solving skill" (p. 76) is simply false for non-routine problems and in ISDs generally.

In addition, the role of long-term memory itself is undergoing a transformation with the ready availability of external media capable of extensive storage, efficient retrieval, and the speedy execution of routinized tasks. Kirschner et al. (2006) claimed, "long-term memory is now viewed as the central, dominant structure of human cognition. Everything we see hear and think about is critically dependent on and influenced by our long-term memory" (p. 76). And, "The aim of all instruction is to alter long-term memory. If nothing has changed in long-term memory, nothing has been learned" (p. 77). Even if technological developments go no further than the widespread use of Google, it can be fairly said that all bets may be off with respect to the role of long-term memory in cognition. That extensive external "memories" will require a re-calibration of cognitive theory is a commonplace, with an accompanying belief that this will free capacity for more inferential and creative (i.e., constructive) activity (e.g., Pink, 2006).

In Sum: The Case Against Direct Instructional Guidance in Ill-Structured Domains

In well-structured domains, we agree that concepts can be directly instructed, fully explained, and simply supported—and more often than not they should be. Yes, the data favor direct instructional guidance (Mayer, 2004; Kirschner et al., 2006), but most of this data is from well-structured domains like physics and mathematics, with a sprinkling of other domains (e.g., aspects of early reading development, but not as many aspects of reading comprehension; Rosenshine & Stevens, 1986). It could be said that direct instructional guidance approaches have been validated for just those domains where essential information was most identifiable and full explanation most viable—i.e., where those approaches were most likely to work. Early graphophonemic development, beginning math, and introductions to the orderly foundations of some areas of science can all benefit from direct instruction. But, this is not *possible* in an ill-structured domain. Therefore, the argument in this chapter is that there is *no alternative*, *in principle*, to constructivist approaches in learning, instruction, mental representation, and knowledge application for ill-structured domains. This argument is not made on an empirical basis, that such approaches work better than direct instructional guidance approaches. Rather the argument is made *in principle*. That which direct instructional guidance advocates call for is just that which is absent, that which makes domains ill structured. Any identified absence of supporting empirical data for constructivist approaches in ill-structured domains—these *have* been less studied—is irrelevant. Even if constructivist approaches had been widely shown not to work in ill-structured domains (though there is empirical evidence from controlled experiments for some success inducing transfer using the constructivist approach of Cognitive Flexibility Theory in ISDs; e.g., Jacobson & Spiro, 1995), it does not matter. We have no other choice. The principles of direct instruction—at least in the strong presentation of those principles in the quotes above—do not apply to ill-structured domains (and, again, the reviews arguing for direct instructional guidance in instruction do not cite studies in ISDs, on the whole, so there is no evidence of a better way on the direct instruction side). We cannot teach something the wrong way just because we have not perfected the right way. We need to find a way to teach ISDs that respects and reflects the nature of those domains. We as researchers need to *try harder*. Too much direct instructional guidance produces dependence on support, when what is most needed in ISDs—where anticipating all the guidance that might be needed is impossible and best efforts to do so can not help but misdirect learners—is *independence*. This will mean some kind of constructivist approach. The question is what kind, and how will it provide its own unique kind of support different from the kinds direct instructional guidance approaches provide for WSDs.

An example of a moderate (or "middle path") kind of constructivist approach to learning and instruction in ISDs is Cognitive Flexibility Theory (CFT). CFT is not a direct instructional guidance approach. But neither is it a discovery approach or a more extreme form of constructivism that opposes the provision of guidance. CFT provides guidance ... because it *must*. Learning in ISDs would be overwhelming otherwise. It is the particular way that CFT instruction and the associated guidance is tailored to the needs of learning in ISDs that distinguishes it in fundamental ways from direct instructional guidance approaches. (Other constructivist approaches also take a "middle path" between direct instructional guidance and more radical forms of constructivism; see, for example, Bransford & Schwartz, 2000; Duffy & Jonassen, 1992; Tobias, 1991.)

Space does not permit (and this is not the appropriate venue) for a detailed presentation of CFT. The interested reader can find many discussions of CFT, the associated learning environments based on CFT over the theory's 20-year history, and empirical tests of the theory (e.g., Jacobson & Spiro, 1995; Spiro et al., 1988, 2007; Spiro, Feltovich, Jacobson, & Coulson, 1992; Spiro & Jehng, 1990; Spiro, Collins, Thota, & Feltovich, 2003; Spiro, Collins, & Ramchandran, 2006). Suffice it for present purposes to say that CFT was developed as a reaction to difficulties Spiro and his colleagues sensed with schema-theoretic approaches (including his own; for that critique of schema theories, see Spiro, 1980; Spiro & Myers, 1984; Spiro et al., 1987). The problem was the one we have been discussing, domain ill-structuredness. In an ISD, one cannot have a prepackaged prescription for how to think and act. You cannot have a precompiled schema that can be instantiated for whatever the situation at hand may be if those situations vary too much, one to the next. Rather, in ISDs, a schema-of-the-moment for a new situation has to be built out of fragments of knowledge and experience that may never have been combined before. To prepare for that kind of situation-sensitive knowledge assembly drawing upon a wide range of unanticipatable knowledge-activation patterns, CFT-based systems facilitate a nonlinear criss-crossing of knowledge terrains to resist the development of oversimplified understandings and to develop connections between fragmentary knowledge sites on multiple dimensions to support maximum adaptive flexibility in the later situation-sensitive assembly of knowledge and experience to suit the needs of a new comprehension or problem-solving event.

A key feature of CFT is that its recommendations for ill-structured aspects of knowledge domains are in most ways the *opposite* of what works best in WSDs. Dimensions for which this is so include the following (again, see the cited CFT papers for explanations). Instead of narrowing to some ideal schema, explanation, or prototype example, *expand* to *multiple representations* (because some will be better in some situations and others will work best in other places); rigidly specified, pre-defined representations need to be replaced by open ones (for increased adaptability across highly variable contexts of application in ISDs); the *atomistically decomposable* knowledge of WSDs does not work, by definition, in ISDs, and must be replaced by the naturally occurring integration of components and ecologically based interconnectedness and non-additivity that occurs when real-world cases are the starting points for all instruction; adaptive assembly of knowledge is cultivated as a primary alternative to the retrieval of intact structures from long-term memory. These are just a few of the opposite directions of instruction from WSDs that CFT promotes.

Not surprisingly, these differences in instructional tendencies will be accompanied by differences in the nature of guidance and support. The point of agreement with Kirschner, Sweller, and Clark (2006) is that support is needed. The point of disagreement is what kind of support is required. CFT *balances* the acceptance of the necessary additional cognitive *complexity* and the effort to make the mastery of that complexity cognitively *manageable*. This has always been the primary challenge at the center of learning-environment design based on CFT. Space does not permit a description of the many ways that CFT-based systems achieve the aforementioned balance, so the reader is directed to the cited papers (all of which are available at www.cogflex.org).

The Future of Constructivist Learning: The Post-Gutenberg Mind and Deep Learning on the Web

We are just beginning to enter a new world of learning that is potentially available with the Web. The authors have been contending (see Spiro, 2006a, 2006b, 2006c for a summary of the argument) that more advanced forms of complex learning in ill-structured domains are becoming possible with:

1. advanced Web-exploration skill, especially in the development of the ability to dynamically generate complex search queries that permit a learner to

navigate with a fair degree of precision through the world of interrelated knowledge on the Web without having to rely on precompiled hotlinks or on sequential clicks through a Google list;
2. an *opening mindset*, as contrasted with the too-typical mindset of closing toward the finding of facts and "answers" on the Web; and further with
3. high-speed connections and increasingly more precisely targetable search engines that permit pertinent (though often unexpected and thus *serendipitous*) connections to be found, to be more likely to be noticed, and to stick in memory.

We refer to this constellation of learning developments as the New Gutenberg Revolution, with the associated nonlinear ways of thinking so suited to ISDs called the Post-Gutenberg Mind (see Spiro, 2006a, 2006b, 2006c, 2006d, 2006e and Spiro et al., 2007). This learning can be both *deep* and *fast* (as empirically demonstrated in DeSchryver & Spiro, in press). Reading a single book on a topic that would present only that author's *swath* through the subject matter does not present the multiple perspectives and many alternative points of connection that criss-crossing a Web landscape permits and can to an ever-increasing degree support (with the aid often coming for free in Web environments themselves with such tools as Google History and ClipMarks). This multiplicity and interconnectedness makes possible many potential situation-sensitive knowledge-assembly paths to build "schemas of the moment" to suit the needs of unforeseeable future situations, as is required in ISDs.

Space will not permit us to go into extensive detail on these arguments or the impressive findings so far from the empirical research that has begun to test the arguments. Detailed reports are available (DeSchryver & Spiro, in press, and the Spiro, 2006 papers cited above) and others are forthcoming. The point for the present chapter is that the affordances of the Web for deep learning in ISDs are unlikely to occur without unfettered searching that unfolds dynamically over time as a function of what is being found and the proclivity to have future learning moves be shaped in turn by those findings in continuous and reciprocal interaction of learner and Web. Direct instructional guidance would interfere with the latter ideal.

Further, the Web allows each learner to find their own way into the web of knowledge they are trying to master, with everything then reachable from wherever that learner had found the ideal entry point for him or her. This is a kind of spontaneous customizability of learning. Direct instructional guidance approaches would militate against this free adaptive personalization of naturally occurring "instruction" that the Web can offer. (It is "natural" in the sense that one learns eventually to "drive" through the landscape of knowledge with as little attention to the steering wheel—Google in this analogy—as is paid to steering a car through a real landscape.)

Of course, all of this depends not only on learners having appropriate mindsets for complex learning in ISDs, as described in the preceding sections, and advanced skill in Web exploration, but also on the use of critical evaluation skills to determine the trustworthiness of information (something that could be partly taught with direct instruction). Even here, however, our findings are surprising. For example, blogs, unreliable as they are, turn out to be very useful for learning once the learner has acquired enough knowledge to realize where the blogger is on shaky ground. The learner can then use the opportunity of virtually counter-arguing to strengthen knowledge in the domain rather than threaten it (DeSchryver & Spiro, in press).

We argue that the more explicit and detailed the subject-matter guidance provided, the less likely the potentially salutary effects of Web-based learning are to occur. We are confident that it will soon be definitively shown that the Web can make possible orders of magnitude increases in usable knowledge per unit of learning time. That definitive demonstration has not yet been made. *However*, given that the availability of so much of the world's knowledge, in easily accessible *random-access* form, has only within the last few years become a fact, and given the plausibility of the arguments for new kinds of learning tied to the affordances of this new medium, the *possibility* of radical improvements in learning in a constructivist mode becomes a pressing hypothesis to be put to rigorous empirical test.

The world does not go in a line, and now learning media can opportunistically follow the natural, nonlinear contours of the world rather than artificially straightening those contours and then hoping the learner can independently bend them back later as needed. We believe the Web is the efficient learning medium of the future for constructing adaptively flexible knowledge in ISDs. We also believe direct instructional guidance would interfere with the independence, opportunism, and ongoing flexible response that learning in reciprocal interaction with the Web seems to require.

Concluding Remarks: The High Stakes of Learning in Ill-Structured Domains

The central argument of this chapter is that successful learning with direct instructional guidance approaches is *impossible in principle* for ill-structured aspects of knowledge domains. This is because direct instructional guidance approaches, as explicitly characterized by Kirschner et al., emphasize kinds of guidance and support that are antithetical to the needs of learning in ISDs. There is little if any empirical backing for direct instructional guidance in ISDs, and it is unlikely that any will be forthcoming. ISDs do not have essential and routinized features to provide by direct instruction by the very nature of their ill-structuredness. The only alternative is constructivist, notwithstanding any difficulty in learning and instruction that *may* be a concomitant. Alternative forms of guidance and support for constructivist learning and instruction in ISDs must continue to be developed and studied, especially in the context of what might be the ultimate—and free—constructivist learning environment, the Web. The fact that this may be hard is all the more reason to proceed with speed and determination.

We conclude simply with the contention that this problem matters *a lot*. Not only is the prevalence of ISDs significantly underestimated, but the most important challenges we face as a society (e.g., the tradeoff between security and civil liberties in an age of terrorism; the achievement gap in education; health care) and even as a species that hopes to survive (e.g., climate change) are riddled with complex ill-structuredness. How can we expect people to make informed decisions about, say, supporting different candidates' positions on these issues if we do not find better ways of fostering understanding at this level?

So, we issue a "call to arms." Between the affordances of nonlinear digital media, including the Web, for learning in ill-structured domains, and the societal need at the professional and especially the "grand social challenge" level, the ultimate constructivist story is unfolding. The kind of learning that is most needed at this time in history can meet the coincidentally available new media with the potential to meet those needs. A generation of children is growing up immersed in nonlinear, random-access environments and is thus better prepared than previous generations for this form of processing, if they are better directed to use it than they have been so far. Even if only a *fraction* of the epochal claims of this New Gutenberg Revolution/Post-Gutenberg Mind hypothesis (Spiro, 2006a, 2006b, 2006c, 2006d, 2006e) turn out to be true, it would still be the learning event of our age, and one that deserves the full attention of educational psychologists and learning-science researchers before it happens without us, causing the world to ask how we missed so large a story that was right under our nose.

So, there is no choice. Learning in ISDs must be done right, and direct instructional guidance approaches are the wrong tools for the task. If that is a difficult challenge, it is nevertheless one we must face. We as a field must find ways to guide and support learning in ISDs that is tailored to the special needs of those domains. This is much more than an academic debate on the merits of different instructional approaches. The more critical the societal issue, the more likely it is to be an ISD. We can do better at teaching toward these "grand social challenges." We *must* do better. The stakes are incredibly high.

Question: Rosenshine. *Reading comprehension, as you noted, is not a well-structured domain. Yet, as I wrote in the article that you cited (Rosenshine, 2002) as well as in my chapter in this volume, there have been a number of intervention studies that have successfully helped students make gains in comprehension as measured by standardized tests or experimenter-developed tests on reading. These studies did not teach reading comprehension skills directly, rather, the investigators provided students with prompts and supports and provided practice and feedback as the students learned to use these prompts and supports. And, as a result of this support and guidance, student scores in reading comprehension improved compared to the scores of the control students. Many authors referred to their procedures as "direct instruction." Would you say that this use of scaffolding and prompts is an example of "direct instructional guidance"? How do constructivists teach reading comprehension?*

Reply: Spiro and DeSchryver. We think it is fine to call this "direct instruction." Much of the problem in this debate has been attributable, we think, to semantic confusion about the use of that term, which we think is a red herring. Unless one is talking about pure discovery learning, most constructivist instruction—definitely including Cognitive Flexibility Theory!—calls for some form of learner support and instructors telling learners *something*. The problem occurs when this generic reference to direct instruction becomes conflated with a more specific recommendation for the form direct instruction should take. In our chapter we point to Kirschner et al. (2006) and their strong and clear dicta to provide "essential information" and "full explanations." There is no question this is just the ticket for teaching, say, Newtonian mechanics or how to use a complex piece of equipment. However, in ill-structured domains (more precisely, ill-structured *aspects* of knowledge domains), which are ill structured precisely because their common core of essential information accounts for only a small part of the knowledge needed and because a priori full explanations must be replaced by situation-sensitive assembly of explanations out of explanatory fragments, the Kirschner et al. recommendations militate against successful learning (see references to empirical studies in our chapter). Where there isn't a substantial core of essential information across occasions of knowledge application, and explanations fully provided in advance don't generalize adequately across situations, constructivist approaches are the only alternative to the aforementioned strong form of instructional advice offered by Kirschner et al. (because the domains wouldn't be ill structured if their advice *could* be followed!).

So what about reading comprehension strategy instruction? Look at some of those strategies, for example, "connect the text to prior knowledge and experience." As has been amply shown, the use of background knowledge in comprehension is a process that is highly ill structured. It happens in so many ways that you could never reduce it to its essentials or fully explain how to do it. So you will need to directly instruct, as you point out, but that instruction will start to look more like "*instruction to construct*" (accompanied, as you say, by feedback, prompts, and supports) than it will resemble the strong form of the Kirschner et al. recommendation.

How do constructivists teach reading comprehension? From the point of view of Cognitive Flexibility Theory (CFT). You will have to see our cited papers for details, given space limits here. Here we will simply note a few examples of first steps CFT takes in its instructional systems that differ from the Kirschner et al. recommendations. At the level of "ways of thinking" or "epistemic stance" or "mindset" (Spiro, Feltovich, & Coulson, 1996), a starting point of instruction in CFT for ill-structured domains is that it tells learners to *not* expect to find too much essential information and supports them in beginning to see, for example, how concepts *vary* across their permissible family of applications. The mindset that is instilled by demonstration encourages learners to begin with presuppositions (for ill-structured aspects of domains) like: "It's not that simple"; "It depends"; "piece together explanations and information from different parts of memory and don't count on retrieving schemas that provide full explanations or prepackaged prescriptions for how to think and act"; and so on.

Question: Klahr. *You use Wittgenstein's famous example of games as an ill-structured concept, and then go on to argue that "there is* no alternative, in principle, *to constructivist approaches in learning, instruction, mental representation, and knowledge application for ill-structured domains" (your emphasis). But how could someone without knowledge of any games understand Wittgenstein's point? Wouldn't someone with a detailed understanding of the rules of, say, baseball, poker, squash, chess, Nim, pattie-cake, Tetris, and rock-scissors-paper be in a much better position to understand games as an ill-structured concept than a space traveler with no knowledge of any game who happened to pick up* Philosophical Investigations *and browse through it while refueling his spaceship? And wouldn't a few hours of direct instruction in the rules of each of those games put our intergalactic visitor in a better position to understand this particular ill-structured domain than would an equal amount of time wandering around a Pirates–Cubs game trying to discover what all those earth-creatures were doing on the field?*

Reply: Spiro and DeSchryver. Our answer is absolutely yes to all of it. But we don't see how this poses any problems for us. As we said in our chapter, any essential information that can be explicitly provided and any procedures that can be fully explained, should be. The chapter is also very clear on not being supportive of pure discovery procedures in most cases. So, we're in agreement: no wandering around at a Pirates–Cubs game for your intergalactic visitor. Teach the rules of lots of games (that have rules; not all games do). Provide full explanations and worked examples for rock-scissors-paper. Just don't teach the "rules" for what makes something a game *in general*, don't overly rely on the "essential information" to know about "games," etc.

Now, in the preceding sentences substitute for the word "games" domain names such as "Renaissance" (or "Renaissance Art," or "Da Vinci's Paintings," or "*Mona Lisa*"). Or, if you prefer something seemingly more solid, substitute the biological concept "Adaptation" (a topic of similar dispute as to its well-structuredness). For all of these, the problems with teaching "games" *as a domain* that we discussed in the preceding paragraph become greatly magnified. Now you will find a lot less in the way of rule-based regularity for the individual cases than we found for instances like rock-scissors-paper. And the variability across instances of, say, "Renaissance Artifacts," will be greater, making the learner's *reliance* on having essential information and generalizable full explanations an even greater danger. Yes, there is *some* essential information. But it must be presented along with the proviso that that information be treated as only a part of what learners need to be thinking and doing—and that substantial remainder will involve more constructivist support.

There is some essential information that can be provided to help learners learn about Michelangelo's *David*. But that will barely scratch the surface. Look at one further example: Sweller, in his response to our questions, points to some new work from his lab on explicit instruction in ill-structured domains. That work is in domains like music. Looking at the dissertation referred to, the problems of pitch, timing, and so on that that study looked at are clearly well-structured aspects of the music domain, amenable to Kirschner et al.'s. However, what would happen with the ill-structured aspects seems not to be addressed in that study. Let's make sure we don't overgeneralize from empirical results that deal only with the well-structured aspects of domains that may be largely ill structured and prematurely write of constructivist instruction on that basis.

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