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8 Epistemology or Pedagogy, That Is the Question

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Epistemology or Pedagogy, That IS the Question

At the time of writing, there is an animated debate which has apparently split the educational world—both teachers and researchers—into two ideological factions. The first faction is depicted as old-school pedagogues who believe that all teaching and instruction should be based upon classical, sage-on-the-stage, expository and didactic approaches of universal truths. The second faction is depicted as fuzzy-brained social constructivists who believe that nothing is true and that learners can only learn by constructing their own knowledge and behaviors through undirected experiences. This debate has infiltrated every pore of our discussions on teaching, learning, and education at scientific and professional conferences, in scientific and professional journals, and, in many countries, even the mass media and national politics.

Of course we, as rational right-minded people, know that neither faction is correct and that the "truth" lies in the middle. For this reason I will try to avoid this ideological discussion and concentrate on a deeper underlying question, namely whether we are selling ourselves and our children short when we use or substitute an epistemology of a domain for a pedagogy for teaching in that domain. Before beginning, I need to define these two terms.

Epistemology and Pedagogy

Epistemology is the study of knowledge and what it means to know something (Shaffer, 2007). It is a branch of science that studies the nature, methods, limitations, and validity of knowledge and belief and addresses questions such as: What is knowledge? How is knowledge acquired? What do people know? In more pedestrian terms, it studies the way someone practicing a profession understands her or his profession and gains new knowledge in that profession. For the natural scientist, it could be the "scientific method" often carried out in teams. For the anthropologist it could be ethnographic or descriptive/deductive research from within, as part of a group or society being studied. And for the philosopher it could be dialogic in debate with others.

Pedagogy, on the other hand, is the art or science of being a teacher, generally referring to strategies or styles of instruction. A pedagogy can be (1) *general*, as in the strategies, techniques, and approaches that teachers use to facilitate learning in general; (2) *specific to a domain*, such as the application of specific strategies, techniques, and approaches belonging to a domain (i.e., professional or pedagogical content knowledge) to the instruction of that specific domain (e.g., mathematics, English as a second language, music); or (3) *specific to a certain approach to teaching* that may or may not be domain specific, such as work-based pedagogy (i.e., the organization of the social activities, organizational structures, and cultural practices by which newcomers, such as student interns, come to acquire and engage that knowledge (Hughes & Moore, 1999)), problem-based pedagogy (i.e., "an approach to structuring the curriculum which involves confronting students with problems from practice which provide a stimulus for learning" (Boud & Feletti, 1991, p. 21)), or even constructivist pedagogy (i.e., the "creation of classroom environments, with goals that focus on individual students developing deep understandings in the subject matter of interest and habits of mind that aid future learning" (Richardson, 2003, p. 1627)).

Having made this distinction, the next step is to look at learners. The next section will deal with learners and their characteristics (i.e., their cognitive development and their expertise) and why the epistemology of practicing in a domain is not a good pedagogy for learning that domain.

Learners

There are two major problems with using a domain's epistemology as its pedagogy. The first is rooted in developmental psychology and biology where Luria and Piaget long ago made clear that children or adolescents (i.e., typical learners in initial education: preschool through university) are not miniature adults. Luria discussed the metamorphosis of a child into an adult as follows:

> The incorrect belief that children and adults differ only in quantitative terms has become firmly entrenched in the general consciousness. Its proponents argue that if you take an adult, make him [*sic*] smaller, somewhat weaker and less intelligent, and take away his knowledge and skills, you will be left with a child. This notion of the child as a small adult is very widespread ... essentially the child is ... in many respects radically different from the adult, and [that he] is a very special creature with his own identity ... qualitatively different from the adult.
>
> (Vygotsky & Luria, 1930/1992, Chapter 2)

In Piaget's view (1955), cognitive development, which he called development of intelligence, is based upon *assimilation* of newly experienced phenomena in already existing cognitive schemata and *accommodation* of those schemata in cases where the new information does not match the existing schemata. In his words, intelligence "progresses from a state in which accommodation to the environment is undifferentiated from the assimilation of things to the subject's schemata to a state in which the accommodation of multiple schemata is distinguished from their respective and reciprocal assimilation" (n.p.). This process proceeds through a series of what he called *cognitive stages*, each characterized by a general cognitive structure that affects all thinking. Each stage represents how reality is understood during that stage, and each stage, except the last one, is an inadequate approximation of reality. In other words, learners—at least those in initial education—see the word differently from practitioners, interpret and understand it differently, and are not capable of carrying out the abstract cognitive transformations necessary for true knowledge construction. Such learners apply inadequate, often faulty novice theories that differ greatly from the sophisticated theories of a domain or the world held by practitioners (Chi, Feltovich, & Glaser, 1981; Mazens & Lautrey, 2003; Partridge & Paap, 1988). As Hannust and Kikas (2007) state in their research on experimentation for teaching children astronomy, children

> acquire factual information rather easily and therefore early instruction should introduce the core facts related to the topics. Some children over-generalized new knowledge very easily, indicating that the materials used in teaching may promote the development of non-scientific notions and that those notions must be addressed promptly to avoid the development of coherent non-scientific models.
>
> (p. 89)

Even if we concentrate on teaching for and learning by those who might be able to think abstractly and carry out the necessary cognitive transformations to think inductively and construct theories, we are confronted with a second problem when using epistemology as pedagogy, namely that learners or novices are not miniature professionals or experts. Experts not only know more and work faster than novices, they also deal differently with problems and solve them in different ways. Here follows a number of ways that novices and experts differ.

De Groot (1946, 1978) determined that chess grand masters, when determining what the next move should be, do not consider more moves than less highly ranked expert chess players, but "zoom in" on potentially good moves earlier in their search than "weaker" players. As Gobet and Simon (1996) state, "stronger and weaker players examine nearly the same number of branches, but ... the stronger players select more relevant and important branches ... because of their greater ability to recognize significant features" (p. 53). This ability to better recognize significant features was also found by Boucheix, Lowe, and Soirat (2006), noting that when viewing animations of the working of a defective piano, expert piano tuners fixate on areas of the animations that contain crucial but less-conspicuous content more frequently than novices who tend to fixate on high-salience information, neglecting less-conspicuous aspects necessary for building high-quality mental models.

> Cuthbert, du Boulay, Teather, Teather, Sharples, and du Boulay (1999) in their review on expert-novice differences in diagnostic medical cognition, determined that: experts produce fewer, but more general hypotheses ... at an earlier stage of problem formulation than novices. Furthermore, experts

> work from findings to a hypothesis (forward reasoning) using a breadth first approach (considering and evaluating several hypothesis at once) … novice reasoning is characterised as backwards (from hypothesis to data), and furthermore, depth first (considering and evaluating a single hypothesis at a time). Experts also demonstrate superior hypothesis evaluation skills, in particular, they are better able to disregard discredited hypotheses and are more likely to change their hypothesis to fit the data than to change the data to fit their hypothesis or to ignore inconsistent findings altogether.
>
> (pp. 23–24)

In other words, the differences between experts and novices manifest themselves not only at the conceptual level, but also at the level of epistemology and ontology (Jacobson, 2000).

Other areas where much research has been carried out on expert–novice differences are physics (Chi et al., 1981; Hardiman, Dufresne, & Mestre, 1989), computer programming (Adelson, 1981), mathematical problem solving (Shoenfeld & Herrmann, 1982), and teaching (Hogan, Rabinowitz, & Craven, 2003). Bransford, Brown, and Cocking (1999) conclude that this body of research shows that:

> it is not simply general abilities, such as memory or intelligence, nor the use of general strategies that differentiate experts from novices. Instead, experts have acquired extensive knowledge that affects what they notice and how they organize, represent, and interpret information in their environment. This, in turn, affects their abilities to remember, reason, and solve problems.
>
> (p. 19)

Donovan, Bransford, and Pellegrino (1999) present six major differences between experts and novices, four of which have concrete bearing on how we teach and learn. The first is that experts *attend to* and *notice* more important features or meaningful patterns of information in a problem or a situation than novices. As stated, eye-movement research has shown that experts fixate on crucial though less-conspicuous content more frequently than novices who fixate on high-salience information, neglecting less-conspicuous aspects that are necessary for building high-quality mental models (Boucheix et al., 2006). Learners miss the necessary basic domain knowledge to do this, and concentrate on superficially conspicuous information, regardless of its actual importance (Lowe, 1999, 2004).

This variation in attending is most probably due to the second major difference, namely that experts have a great deal of *accessible content knowledge* organized to reflect deep understanding of the subject matter. In other words, what experts already know determines what they see and how they see it. Because novices know little about a subject or a domain, they do not know where to look and, having looked at something, have trouble correctly interpreting what they have seen.

The third difference is that the experts' knowledge is not simply reducible to sets of isolated facts or propositions, but reflects "*contexts of applicability*" of that knowledge. Donovan et al. (1999) called this *conditionalized* knowledge, though it could also be called *contextualized* or *situated*. It means that experts have a type of knowledge that includes knowledge of the contexts and/or situations in which it is or will be useful. In contrast, a novice's knowledge is often *inert* (Whitehead, 1929); it has been learned but cannot be accessed for problem solving.

The fourth difference (Donovan et al., 1999) is that experts *retrieve* important aspects of their knowledge with *little effort* whereas novices spend a great deal of effort attempting to remember and process individual knowledge elements. Experts have many and varied rich cognitive schemas at their disposal in which their knowledge is organized and from which needed aspects of that knowledge can be easily and quickly retrieved (Glaser & Chi, 1988; Schneider & Shiffrin, 1977). Larkin (1979) found that physics experts remember sets of related equations while novices retrieve a series of single equations, suggesting sequential memory search. "Experts appear to possess an efficient organization of knowledge with meaningful relations among related elements clustered into related units that are governed by underlying concepts and principles" (Bransford et al., 1999, p. 26).

In other words, applying an epistemology used by domain experts or practitioners as a pedagogy for learning in that domain will not work. In the following, I will look at this problem within a specific and well-studied domain, namely the natural sciences.

Practicing Science or Learning to Practice Science?

Curriculum reform in the natural sciences has emphasized the experience of the processes and procedures of science, moving away from the teaching of science as a body of knowledge (Bybee, 2003; Harmer & Cates, 2007; Hodson, 1988). Bybee stated that

> students learn by constructing their own meaning from experiences [and] … that science teaching should consist of experiences that exemplify the spirit, character, and nature of science and technology … inquiry-oriented laboratories are infrequent experiences for students, but they should be a central part of their experience in science education.
>
> (Bybee, 2003, n.p.)

In 1996, the National Research Council declared that inquiry into authentic questions generated from student experiences should be the central strategy for teaching science. In 2005, Gabric, Hovance, Comstock, and Harnisch stated that

> the ultimate goal was to provide a learning environment in which students could feel like scientists in their own classrooms. This meant that our students would need to be involved in the acquisition of their scientific knowledge by – not only reading and writing about – but actually doing science.
>
> (p. 80)

This focus is coupled to the assumption that to teach the process of science (i.e., the pedagogy), we can best confront learners with experiences either based on or equivalent to science procedures (i.e., the epistemology). This has led to a tenacious commitment by educators, instructional designers, and educational researchers to discovery and inquiry methods of learning which is based upon confusing teaching science *as* inquiry (i.e., an emphasis in the curriculum on the processes of science) with teaching science *by* inquiry (i.e., using the process of science to learn science). The error here is that no distinction is made between the behaviors and methods of the scientist—who is an expert practicing her or his profession—and those of a student who is essentially a novice.

Even if this were true—and now I play devil's advocate—the epistemology used in school science is that of the inductive, positivist scientist. Cawthron and Rowell (1978) described this as a "conception of scientific method as ... a well defined, quasi-mechanical process consisting of a number of characteristic stages" (p. 33). It is as though scientists look at the world with no a priori ideas and that they objectively observe, collect, record, analyze, and interpret without underlying hypotheses or preconceptions except those relating to the logic of thought processes. This objective, impartial, and unbiased scientist finally draws conclusions about relationships and makes generalizations about an observed phenomenon based upon the facts collected. It seems as though "constructivist" educators and curriculum designers see the domain taught as being "positivist", containing general and identifiable truths. Southerland and Gess-Newsome (1999) confirmed this, describing even those teachers who had learned science through modern, discovery-based curricula as a form of discovery maintain positivist views of knowledge, learning, and teaching. Discovery, thus, becomes trivialized to "stage-managed pseudo-discovery of the inevitable" (Hodson, 1985, p. 40).

But I digress. Returning to the main point, it is clear that many curriculum developers and instructional designers either are not aware of or do not see the distinction between the epistemological basis of the natural sciences and the pedagogic basis for teaching the natural sciences. Because experiments are widely used in science, science teachers are conditioned to regard them as a necessary and integral part of science education. But students do not practice science. They are learning about science and/or learning to practice science. It is the teacher's job to teach science, teach about science, and teach how to do science.

A student, as opposed to a scientist, is still learning about the subject area in question and, therefore, possesses neither the theoretical sophistication nor the wealth of experience of the scientist. Also, the student is learning science—as opposed to doing science—and should be aided in her/his learning through the application of an effective pedagogy and good instructional design.

We find these concerns in educational and psychological literature as far back as Ausubel (1964) and as recently as Klahr and Nigam (2004) and Mayer (2004). Ausubel expressed problems that accompany the failure to differentiate between the scientist and the student. According to him, scientists are engaged in a full-time search for new, general, or applied principles in a field, whereas students are engaged in learning the basic subject matter of a field which scientists learned in their student days plus the way in which scientists practice. If students are ever to discover scientifically, then they must first learn both the content as well as how to discover! The student "cannot learn adequately by pretending [to be] a junior scientist" (p. 298). According to Mayer, many phenomena associated with using discovery make it relatively ineffective as an instructional method. Klahr and Nigam state that

> children in discovery situations are more likely than those receiving direct instruction to encounter inconsistent or misleading feedback, to make encoding errors and causal misattributions, and to experience inadequate practice and elaboration. These impediments to learning may overwhelm benefits commonly attributed to discovery learning—such as "ownership" and "authenticity".
>
> (2004, p. 661)

Kyle (1980) described scientific inquiry as a systematic and investigative performance ability which incorporates unrestrained thinking capabilities after a person has acquired a broad, critical knowledge of the particular subject matter through formal learning processes. This same idea is posed as an apparent anomaly by Klahr and Nigam (2004) when they note that "most of what students (and teachers and scientists) know about science was taught to them, rather than discovered by them" (p. 661).

This lack of clarity about the difference between learning and doing science has led many educators to advocate the discovery method as the way to teach science (Allen, Barker, & Ramsden, 1986; Bybee, 2003; Kirschner, Sweller, & Clark, 2006). This approach fits well in contemporary learner-centered pedagogies emphasizing direct experience and individual inquiry (e.g., experiential learning (Kolb & Fry, 1975; Itin, 1999), authentic learning (Downes, 2007), inquiry-based learning (Dewey, 1997), and problem-based learning (Barrows & Tamblyn, 1980; Hmelo-Silver, 2004; Hmelo-Silver & Barrows, 2006)). Cawthron and Rowell—in 1978—had the prescience to characterize this as the coalescing of the logic of knowledge and the psychology of knowledge under the mesmeric umbrella term "discovery."

But to discover (i.e., notice) anything, learners need a prior conceptual framework—as discussed earlier in this chapter when the differences between experts and novices were discussed—as well as the ability to think in abstract ways about what they have noticed (see the earlier discussion on the development of thinking). Discovery, thus, presupposes a prior conceptual framework and the ability to interpret and sometimes reinterpret what has been seen or experienced in abstract terms, but there is no guarantee that it will lead to new concepts, much less correct ones. This is because, first, novices have little knowledge and experience in a domain which causes them to encode information at a surface or superficial level, while experts have much knowledge and experience in a domain and are, thus, able to encode information at a deeper, more structural level (Chi et al., 1981; Novick, 1988; van Gog, Paas, & van Merriënboer, 2005). Second, novices do not simply produce random guesses in the absence of knowledge, "but rather as systematically off the mark in a particular way that makes sense given a particular misconception" (Means, 2006, p. 508).

The strangest and possibly most unfortunate aspect of this whole problem is that this is not new. Novak (1988), in noting that the major effort to improve secondary school science education in the 1950s and 1960s fell short of expectations, stated that the major obstacle in the way of "revolutionary improvement of science education ... was the obsolete epistemology that was behind the emphasis on 'inquiry' oriented science" (pp. 79–80). More recently, Chen and Klahr (1999; see also Klahr, this volume) demonstrated that direct instruction was significantly better than discovery learning on children's ability to design simple, unconfounded experiments, and even more important, those receiving direct instruction were also superior on a far-transfer test of experimental design administered 7 months later.

Conclusion

For designing instruction, Vamvakoussi and Vosniadou (2004) warn that "presuppositions that constrain learning are not under the conscious control of the learner. It is important to create learning environments that allow students to express and elaborate their opinions, so that they become aware of their beliefs" (p. 466). Van Merriënboer and Kirschner (2007) note that there are considerable differences between domain models that describe the effective mental models used by competent task performers and the intuitive or naive mental models of novice learners in that domain. Such intuitive or naive mental models are often fragmented, inexact, and incomplete; reflecting misunderstandings or misconceptions where learners are unaware of the underlying relationships between the elements.

As such, how to learn or be taught in a domain is quite different from how to perform or 'do' in a domain (i.e., learning science vs. doing science). The epistemology of most sciences, for example, is often based upon experimentation and discovery and, since this is so, experimentation and discovery should be a part of any curriculum aimed at "producing" future scientists. But this does not mean that experimentation and discovery should also be the basis for curriculum organization and learning-environment designing (Bradley, 2005; Kirschner, 1992). Modern curriculum developers and instructional designers confuse the epistemological nature of a domain with the psychological bases of learning and the pedagogic bases for teaching. Epistemology refers to how knowledge is acquired and the accepted validation procedures of that knowledge; pedagogy refers to how something is taught.

In the natural and social sciences, for example, the epistemology is often based upon experimentation, discovery, and testing. Curriculum designers using a discovery or inquiry-learning approach operate on the belief that how science is practiced is also the best way to teach and/or learn it. Critics of such inquiry-based instruction such as Sewall (2000), caution that such approaches are over-emphasized at the expense of "carefully prepared lesson(s) ... focused and guided...; interspersed with small group work when appropriate; and with a clear sense of direction at the beginning and summary at the end, leaving all participants with a feeling of completion and satisfaction" (p. 6).

This ambiguity about the difference between learning and doing science, coupled with the current societal prioritization of knowledge construction has led educators to advocate discovery as the way to teach science. But discovery presupposes a prior conceptual framework (Vosniadou, 2002). Via discovery, one can investigate relationships between concepts, but whether this leads to new concepts depends upon the structure and content of existing knowledge. Klahr and Nigam (2004) conclude, based on their empirical findings, that there is a "need to reexamine the long-standing claim that the limitations of direct instruction, as well as the advantages of discovery methods, will invariably manifest themselves in tasks requiring broad transfer to authentic contexts" (p. 666).

The origin of these teaching approaches lies in a failure to distinguish between learning and doing; in overlooking that students are not experts practicing something, but rather novices learning about something. It is the teacher's job to teach science, teach about science, and teach how to do science. It is not the teacher's job to practice science as part of the teaching exercise; leave that to the scientists.

Question: Duschl and Duncan. *A big part of scientific literacy is learning to distinguish scientific claims from pseudoscience and hoax claims. What are the pedagogical strategies that develop learners' abilities to assess the status of knowledge claims presented by the popular media?*

Reply: Kirschner. Van Merriënboer and Kirschner (2007) present a series of pedagogic/instructional-design approaches that are based on realistic (i.e., authentic) whole tasks and that contain the support and guidance needed to achieve the type of learning and abilities that you ask about.

To begin, a well-designed case study could/would present learners with descriptions of actual or hypothetical problem situations situated in the real world (i.e., a claim presented in the popular media) and require them to actively participate in the determination of the validity of that claim. For learning to distinguish scientific claims from pseudoscience and hoax claims, a case study would confront learners with a claim that the popular media has presented (the "given state"), a list of possible research results and/or scientific "facts" that is not too long and that is directly relevant for determining the validity/truth of the claim (criteria for the "goal state"), and worked-out examples of the thinking and possible further search queries for new information necessary to determine the validity/truth of the claim (the "solution"). In order to arouse the learners' interest, it may be desirable to use a case study that describes a spectacular event, such as an accidental discovery, a success story, or a disputed result, et cetera. In a well-designed case study, learners would be required to answer questions that provoke deep processing of the problem state and of the associated operators (i.e., solution steps) so that they can compare that case with other cases in order to induce generalized solutions. By studying the—intermediate—solutions, learners get a clear idea of how a particular domain is organized and what determines "proof" or "refutation."

In our book we discuss many other learning tasks that could be used such as imitation tasks, non-specific goal problems, completion tasks, reverse troubleshooting, et cetera (van Merriënboer and Kirschner, 2007). The common element of all of the learning tasks is that they direct the learners' attention to problem states, acceptable solutions, and useful solution steps. This helps them mindfully abstract information from good solutions or use inductive processes to construct cognitive schemas that reflect generalized solutions for particular types of tasks. The bottom line is that having students solve many problems on their own is often not the best thing for teaching them problem solving! For novice learners, studying useful solutions together with the relationships between the characteristics of a given situation and the solution steps applied is much more important for developing problem-solving and reasoning skills than solving equivalent problems.

Question: Duschl and Duncan. *Without the inclusion of some epistemological elements used by domain experts or practitioners, how do learners progress from novice to expert? When and how do you recommend epistemological elements enter the learning environment?*

Reply: Kirschner. As should be clear by the answer to the previous question, epistemological elements can enter the learning environment very early in the learning process. The clue here is that the epistemology of the expert is not the guiding principle for the pedagogy, but rather that the learning, i.e., the acquisition of that epistemology, is the goal and leading principle.

Question: Herman and Gomez. *What is the relationship between epistemology and pedagogy? Do you mean that no domain-based epistemology can inform classroom pedagogy? Or do you mean something more radical, that classroom-based instruction is (should be) divorced from any coherent epistemology?*

Reply: Kirschner. The "only" relationship between epistemology and pedagogy is based not upon the translation or mapping of an epistemology (on) to a pedagogy, but rather the selection of a fitting pedagogy to "teach" (i.e., help the learner acquire) the epistemology. In other words, the choice of a pedagogy can and possibly must be "informed" by the epistemology that the learner should acquire, but is not the same as making use of that epistemology as a pedagogy.

In addition to the pedagogies discussed in answer to Duschl and Duncan's question is the experimental seminar, a pedagogy specifically designed for undergraduate students in natural sciences to support the acquisition of the epistemology of the natural scientist, first proposed by Conway, Mendoza, and Read (1963). Here, students collectively perform an experiment or watch an expert perform an experiment. This way they gain a clear concept of how a well-performed experiment progresses. Collective experimentation or demonstration is followed by group discussion, where necessary stimulated by an "expert," such as teacher, lecturer, or professor, and in which students can help each other. An experiment which is routine and uninteresting to one or two students can trigger a valuable discussion in a group. This provides the student with a model for problem identification, experimental design, assembling, testing and calibrating equipment, data collection, analysis, interpretation and reporting results. The possibility to model, discuss, reason, and compare methods and results with others is characteristic for this type of practical. An important aspect of the experimental seminar is that it makes use of modeling to facilitate the development of a template necessary for the learner (see answer to Duschl and Duncan).

A second integral aspect of the experimental seminar is discussion. This is what Kollard (1985) calls the didactic translation of observations. To counteract any misconceptions arising from a demonstration, a discussion must round off the demonstration. In this way both relevant and irrelevant observations can be noted and discussed. Discussion also helps promote conceptualization and deeper understanding of what has occurred. Support and guidance in the form of scaffolding the discussion can be seen as the addition of an additional informed opinion. Such discussion encourages students to reflect upon past personal experience and to use it as a means to discover and evaluate solutions to present problems.

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