1. The Fragmented Nature of Learning and Instruction

Remarks on the Philosophy of Science, the Psychology of Learning and the Design of Instruction

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Abstract: This chapter falls roughly into the intersection formed by the philosophy of science, cognitive psychology, and instructional design. I have drawn heavily on notes written for my students that have been read and commented on by Professor Seel in their earlier incarnations. Seel's work on the progressive development of mental models and the implications for the design of instruction have inspired many of my remarks. I regard this general domain of discourse as somewhat like a puzzle with missing pieces and pieces that should fit together well but often do not. It is almost as if the building blocks of instructional systems research were pieces from different puzzles thrown together hastily. The general thrust of my argument is that we do not yet have comprehensive and completely coherent accounts of how people learn and, as a consequence, we lack a complete theory of how best to design instruction and assess its effectiveness. Seel's research over the years represents important steps towards such a comprehensive theory of instruction.

Keywords: Constructionism; instructional design; instructional science; learning theory; mental model.

Remarks on Scientific Inquiry and Instructional Design Research

In a recent doctoral seminar in the Instructional Systems program at Florida State University, Professor Seel asked participants to indicate what each regarded as the single most important research question to be addressed in the next five

years in the domain of instructional systems, broadly and loosely defined to include instructional analysis, design, development, evaluation, management and technology. Answers reflected topic areas rather than research questions. He then asked each student to indicate an appropriate research methodology to address [part or all of] the indicated question. This second request turned out to be problematic since topic areas rather than research questions had been provided by students.

I was struck by two things. First, the notions of *science* and *research* seemed to vary considerably from one person to another. Second, specific responses indicated a strong tendency to only consider those aspects of instructional systems with which a particular individual was engaged, with the implicit assumption being that what each was doing represented the most critical research issue in instructional systems.

What is science? What is the nature of scientific inquiry? What distinguishes scientific research from other forms of research? What do scientists do? There are many answers to such questions. They can be found in books on the philosophy of science and in nearly every introductory text to a particular scientific discipline. I found myself generating such questions during Professor Seel's seminar as various doctoral students provided their responses. I settled on a rough and ready representation of inquiry in physics as a starting point. For centuries, physicists have been asking such questions as these: (a) what kinds of things are there in the universe? and, (b) how do these different kinds of things affect each other? My first thought was that the basic questions within that discipline had remained fairly stable over the years; what have changed are the instruments and tools used to investigate various phenomena, which have led to new answers to basic questions and to improved understanding of the phenomena being investigated. Of course research methods and perspectives have also evolved, partly based on new answers to the basic questions. The basic research questions are basically unchanging. What changes are the tools used to investigate possible answers and the answers themselves. Moreover, interpretations of the basic questions may change considerably over the years; new interpretations of the basic questions might be regarded as representing a new approach, or possibly even a paradigm shift.

For example, Empedocles, (a pre-Socratic physicist who lived circa 492-432 BCE) believed that there were only four basic things – earth, air, fire and water – and that the physical world and our experiences could be completely accounted for in terms of these four elements. Aristotle further elaborated this view of matter and argued that all earthly substances contained mixtures of these four elements, with the particular distribution of the basic elements determining the nature and appearance of a particular object. For example, a rock contained much more earth than air, fire or water, according to Aristotle, which is presumably why rocks are hard, not readily combustible, and not easily transformed into liquid or gaseous forms. Aristotle then identified four kinds of causes: (a) material cause – the basic composition of an object; (b) formal cause – the inherent or underlying structure

of a thing; (c) efficient cause – how the thing came to be in its current state; and (d) final cause – the purpose of an object.

We do not think about the world in the same way as did Empedocles or Aristotle. Physicists no longer accept their accounts of the physical world. In spite of dramatic advances in physics in the last two thousand years, much has not changed. What has not changed are the basic questions: What kinds of things exist and how do they interact? Scientists are still attempting to elaborate adequate answers to these basic questions. Modern answers are that there are some 118 or so elements – a few more than four – and these elements are comprised of more basic building blocks – with leptons, quarks, and bosons being the basic categories for these sub-atomic building blocks. Furthermore, a small number of forces have been proposed to explain interactions among these basic building blocks of the universe – gravity, electromagnetism, weak nuclear force and strong nuclear force.

Okay – I did not recall all of those details late at night after the seminar. I had to look up a few things. My basic line of thought, however, was that this framework might be applicable to Seel's questions. Imagine a door that has this question posted outside: What do instructional design researchers regard as the basic elements and what do they propose as the critical interactions among these elements? Shall I open this door? What might I find inside?

There is someone pulling on my elbow telling me not to waste my time opening that door. This person says that such an account applies only to the *hard* sciences – the physical sciences, such as astronomy, biology, chemistry, and physics. This person says that the *soft* sciences, which include the social sciences and what Herbert Simon (1996) called the sciences of the artificial, are fundamentally different. I understand those distinctions, I think, but there are some common concerns across all the sciences. Basically, what nearly all scientists want to know and understand is what exists – the building blocks – and how these things interact to bring about the things we observe, want to observe or would like to create. While causal interactions might be more difficult to establish in the social sciences, there is still strong interest in understanding, explaining, and predicting critical interactions. While the things that social scientists investigate might not be as precisely defined as those investigated by physical scientists, there is still strong interest in identifying the basic elements that explain what we have observed and are likely to observe in the future.

Perhaps this is a biased or naïve interpretation of science. Perhaps not. Nonetheless, I am going to push that door open and go looking for the basic elements and their interactions in the domain of instructional systems. What will I find?

What are the basic building blocks of an instructional system? What comes to mind immediately are students, instructors, things to be learned, and instructional resources. This might be an earth-air-fire-and-water kind of answer, though. Each of these elements might be further elaborated in terms of more discrete components which are more informative with regard to explaining interactions that are observed or desired.

What are the essential interactions or causal influences in an instructional system? Outcomes common to most instructional systems include improved understanding and performance with regard to some body of knowledge or set of skills. This implies that there should be reliable ways to assess relative levels of understanding and performance (relative to past performance or understanding or relative to a desired standard or goal). Other outcomes might be identified, and these might be further elaborated in terms of types of outcomes (e.g., affective, cognitive, psycho-motor or … there are many ways to cluster outcomes) and their relationship to other knowledge and skills.

Regardless of the sophistication and granularity of the components and interactions, we want to understand the various things that comprise an instructional system and how they are related, especially with regard to efficacy in achieving desired outcomes. Maybe. Well, I seem to recall Robert Gagné saying that our job as instructional designers was to help people learn better. What can we do at a systems level to fulfill that responsibility? How can we measure success? These and related questions represent the overarching areas of inquiry and scholarship in the general domain of instructional design and technology.

Lastly, there is the notion of research issues central to progress in a domain. The students who responded to Professor Seel each had a favorite area of inquiry. Why believe that one's favorite area of inquiry is critical to progress in instructional systems research, however? What evidence can one bring to bear to defend such a view? How might one identify critical areas of research inquiry?

One might think beyond oneself and beyond one's own training and set of predispositions. One might look at what distinguished researchers have said. The *Book of Problems* (see the 2002 events archive at www.learndev.org) would be a good starting point, I would think. That collection includes the contributions of 22 scholars and researchers who were asked by Jan Visser to describe what we do not know about human learning and to identify key unresolved problems. Contributors included a nobel prize winning physicist, a renowned biochemist, a neuroscientist, several sociologists and psychologists, an anthropologist, a number of educational researchers, and the odd philosopher. This collection is well worth a visit – what do such distinguished scholars believe is lacking in our knowledge of human learning? I leave the answer to this question as an exercise for the reader – an eminently worthwhile exercise, I believe.

I recall the advice I was given when searching for a dissertation topic by Professor Ed Allaire: Pick the central domain of inquiry within a discipline and then pick a central unresolved issue within that domain of inquiry that can sustain your interest. Of course there is much subjectivity in this – there will be different views about the centrality of domains and issues. I suspect, however, that a small number of alternatives can be identified. What might these alternatives be for instructional systems?

Addressing that last question is where I thought the discussion might have gone in Professsor Seel's seminar; at least that is where it was going in my mind. What are the central research issues in instructional design? I will suggest a few such issues later in this chapter.

What values are at the core of scientific inquiry? Are values relevant in our work? Of course they are. The starting point of scientific research is a desire to understand a phenomenon or situation or sequence of events. This implies that one admits to a state of relative ignorance: "I do not understand this." One might then say that humility ("I know that I do not know") is the starting point of every scientific inquiry or investigation. Humility would then be one of those core values in scientific inquiry. What do leading instructional systems researchers admit to not knowing or not understanding? That was the focus of Visser's *Book of Problems*. It would be interesting and revealing to find out to what extent academics and practitioners agreed with the things identified in the *Book of Problems*. I have not conducted a survey and am not positioned to answer, but I would propose such an exploratory investigation as relevant for our discipline.

By way of encouragement for others to explore this question, I shall provide a small sampling of contributions to the *Book of Problems*. John Shotter asked this in his contribution:

"To what extent is our living involvement in a whole situation necessary for us to get an *evaluative* grasp of the meaning for action of a small part of it – as when a music teacher points out a subtle matter of timing, or a painter a subtle change of hew, or a philosopher a subtle conceptual distinction, such as that between, say, a *mistake* and an *accident*?"

Vera John-Steiner asked: "How would our understanding of learning be transformed if its purpose were joint discovery and shared knowledge rather than competition and achievement?" Gavriel Salomon noted that "what we'd need to study is what makes socialization and acculturation so effective and how their 'active ingredients' could be incorporated into instruction." Leon Lederman suggested that we should figure out "how to construct a dossier of misconceptions, of 'natural' assumptions that must be viewed with suspicion."

Basarab Nicolescue posed this question: "If we distinguish three types of learning, the mental (cognitive), the feeling (affective) and the body (instinctive), how important are, for a given type of learning, the other two types?" Federico Mayor observed that we do not know much about "learning *to be*, to transform information into personal knowledge" even though we know a lot about learning *to know* and learning *to do*.

David Perkins posed four general questions about learning:

1. The Question of Mechanism - When we learn, in what form is that learning captured in us and our physical, social, and symbolic surround? – in the form of mental representations, the weightings of neural networks, conditioned reflexes, runnable mental models, priming or expectancy and different degrees of primability, distributed cognition, etc.? …
2. The Question of Difficulty - When learning is hard, what makes it hard? When learning is easy, what makes it easy? Answers would have to deal with the match between mechanism and the things to be learned. …

3. The Question of Design - What can we do to make learning something easier? This is the problem of instructional design taken broadly, not just for schools but for groups, teams, families, societies, even for immune systems and genetic codes. …

4. The Question of Worth - What's worth learning, for whom, for what purposes practical or ideological, at what cost? Do we find the guide to what's worth learning … in Adler's great books, in Dewey's pragmatism, in Socrates' insistence that we know our own ignorance, in more humble crafts and skills of the kitchen, the tailor's shop, the chemist's laboratory, the accountant's spreadsheet, in the ancient human modes of love, parenting, friendship, ownership, command, peace, war? …"

In order to conduct sustained scientific investigation, one must be open to alternative explanations – this (what I or someone else has proposed) is one possible explanation; perhaps there are other explanations. Open-mindedness is then a second important value. The inability to imagine alternative explanations does not mean that alternative explanations do not exist. It would be a remarkable coincidence if the limits of reality happened to coincide with the limits of one's imagination. Alternative explanations always exist (this is a remark about the logic of scientific explanations). Humility is the starting point, and openness to alternative explanations is required for sustained inquiry.

Perhaps none of Seel's doctoral students mentioned such things because they are so obvious. I find myself requiring such reminders, though. In answer to Seel's question about important research questions in instructional systems for the near future, I offer this: How can we reliably determine which interventions intended to help improve understanding of complex and dynamic systems are effective, to what extent they are effective, with whom they are effective and why? By way of clarification, I offer a few additional remarks. Complex and dynamic systems, be they natural or artificial, create challenging problem-solving and decision-making situations for humans. In such systems, many problems arise that are not especially well-structured; there may be incomplete information about critical aspects or goals, there may not be one standard or correct solution, there might be multiple approaches to the problem, and there might even be alternative interpretations of the problem situation itself. Complex and dynamic systems are pervasive. Examples include economic policy development, engineering design, environmental planning, instructional design, medical diagnosis, and many more. There are university curricula built around such problem solving areas. How might one go about determining whether and to what extent various curricula that support development of knowledge and skill in solving complex problems are effective? How might the findings of such an investigation be used to improve human understanding and performance in complex problem solving domains? I admit to not knowing the answers to these questions, but I am engaged in trying to find reasonable answers, as are Professor Seel and others.

The Fragmentary Nature of Psychology

From Bob Dylan's Dream:

> As easy it was to tell black from white
> It was all that easy to tell wrong from right
> An' our choices they was few so the thoughts never hit
> That the one road we traveled would ever shatter or split.

One of my graduate students asked about the fragmentary nature of psychology. This question implies that psychology is incomplete or disconnected. Perhaps the request is for an explanation why psychology is incomplete or disconnected. I am not sure. Perhaps I am incomplete and disconnected; I am sure this is often the case.

Suppose we agree for the sake of this discussion that psychology is the disciplined investigation of human thought and behavior. The aim of psychology is to provide a general account of the processes that underlie observable behavior and reported thought processes. As is true in other scientific enterprises, the desired general account will consist of causal factors and underlying mechanisms that explain what has been observed and reported and that predict what is likely to be observed and reported.

Where shall we start? Perhaps we should begin with a familiar phenomenon, such as confusing the names of two people. Suppose this phenomenon is common to nearly everyone – it represents the one road we are now all traveling together. Suppose further that we are all able to easily recognize this phenomenon and know when we have in fact confused one person's name with that of another person – it is easy to tell black from white – at least at the outset. Someone said that in the beginning there was chaos and confusion. Or was it chaos and the void? In any event, this beginning is not like that other one that happened a long time ago.

Now, we are underway. The journey has begun. Let us begin by collecting explanations for this phenomenon. One person says that he confuses X's name with that of Y because X resembles Y. Another person says that she confuses the names of X and Y because she met them both at the same time. Still another claims that the cause for mixing up the names is that the situations in which each person was first encountered were remarkably similar, although X and Y were met separately at different times and in different parts of the world by that person.

We already have three different accounts and we have barely begun. One explanation focuses on physical resemblance and implies a recall mechanism that assumes a search for an association between two kinds of mental representations – one textual (the name) and one visual (the person). Another explanation focuses on storage and retrieval cues, implying that the circumstances in which a person's name is first learned are stored along with that person's name and then used at least sometimes in recalling that person's name. The third explanation also focuses on storage and retrieval mechanisms and also implies links between a retrieval cue (one kind of mental object) and a name (another kind of mental object).

Just as these three different explanations were beginning to coalesce, along comes another person who says that he confuses two people because he likes them both a lot and both remind him of another person. Emotions may also play a role in cognition, at least on some occasions for some people – namely those with emotions. I am heartless and unable to understand this person, so I continue on my way.

Just as I realized that fact about myself, along came yet another person who said that she confuses X and Y because their names are syntactically similar. Let us not overlook the mediating influences of language. Language pervades so much of what we do and learn. How can we properly account for the role that language plays in learning? What tales these twisted tongues will tell. One might even sense a change of language use and tone within this very chapter – even our use of language is fragmented. Back to our investigation of a *simple* phenomenon.

Then a person driving a convertible drove up, stopped and told me that the reason that I confused those two names was that I was in love with them both. Or perhaps I was in love with my deceased mother. Or perhaps with someone else's deceased father. Or just lusting after them for no particular reason. Beware people driving convertibles.

Next there came along a large truck – a moving van, in fact. The driver stopped next to me, unloaded a couch, and invited me to sit down and tell her my troubles. I began to cry realizing that there were just too many possible explanations for this apparently simple phenomenon. She consoled me and gave me a lollipop.

What a strange beginning, I thought. When I looked around after the convertible and truck had driven off, I found myself all alone. Those with whom I had begun this quest were no longer in sight. I suppose they had followed a different bend in the road. Perhaps they escaped to Canada. Then I began to think about that other beginning, the one involving chaos and confusion. I concluded that not much had changed in all the intervening years.

Is it no wonder that psychology is incomplete and disconnected? Humans are complex creatures. Consciousness is especially complex. In the *Tractatus Logico-Philosophicus* Wittgenstein said that we picture facts to ourselves. Is it not remarkable that we are able to do that and then to talk about those pictures with others? We picture facts to ourselves. We also are able to picture to ourselves things that are not facts. Misperceptions, misconceptions, and misinformation account for many of these misleading internal pictures. We picture facts to ourselves. We cannot stop picturing facts to ourselves. This is a natural and ongoing process. Some are apparently able to improve the quality of these internal pictures, but such improvements are difficult to assess because these internal pictures are not directly available for public scrutiny; we cannot even examine our own internal pictures – mental models and schema, if you like. We construct internal representations to make sense of our experiences; these internal representations are hidden from view but affect what we come to believe and how effective and efficient we are able to learn. Is not a critical issue for instructional research the investigation of these internal representations and their role in learning? What interactions might exist between external representations provided by an instructor or a co-learner or oneself and these internal representations? What kinds of internal representations

do we create? When? Why? What kinds of external representations are likely to engender more effective internal representations and result in improved learning (and, of course, with whom, when, and why)? Professor Seel is exploring this question, as are others, including myself. Given what we know and do not know about the human mind and its development, answers are quite fragmented at this point in time.

Recognizing Patterns

One of the most remarkable statements I have encountered is also one of the simplest. It is this: "Wir machen uns Bilder der Tatsachen," which has been translated from the German as "We picture facts to ourselves" (Wittgenstein, 1961). I mentioned this in the previous section and implied that these internal pictures are one of the basic building blocks of learning and instruction. Is this not a remarkable statement – we picture facts to ourselves? Is it not a remarkable ability? To highlight why this is so remarkable, perhaps a short philosophical sojourn is in order. Such a sojourn is consistent with my conception of *philosophy as thought in slow motion*.

We picture facts to ourselves. Or, more literally, we make for ourselves pictures of actualities. Making such internal pictures is not at all like drawing a sketch of something. We can observe a person making a sketch. Many people have drawn sketches while sitting in philosophy classes listening to boring lectures on epistemology. Some sketches are made more or less thoughtlessly, but many are constructed intentionally to represent something. Sketches are typically created on flat surfaces in one or more colors. They may or may not bear some resemblance to an object in the surroundings of the person making the sketch. So, we make sketches – that is not so remarkable, although drawing is a skill that can take years to master. This other ability, though, is something else. We make pictures to ourselves. How long did it take to learn to draw internal pictures? No time at all, although perhaps one can improve with practice – a serious matter well worth investigating, this last claim. Where is the hand that draws the picture? Oh, no hand is involved with internal pictures. Where is the flat surface on which the image is drawn? Oh, there is no such surface. Where is the crowd that gathers to watch the image being drawn? Oh, no one can observe this process, not even the person making the internal picture. Oh.

Is this statement – *we picture facts to ourselves* – a metaphorical remark, then? What can it mean? It seems to be a critical claim in Wittgenstein's *Tractatus Logico-Philosophicus*, and it is closely related to concepts fundamental to cognitive science. It does seem worth exploring a bit more, especially since most people seem to accept it as obvious and non-problematic. Only the odd beast – the philosopher – draws attention to such apparently simple claims. Somehow or other we seem to build up an understanding of our surroundings, including other people and unusual phenomena we encounter. Moreover, we have a nearly irresistible urge to talk about our experiences and our surroundings, especially odd people and unusual phenomena. How is this possible?

Apparently, humans excel at recognizing particular images and patterns. Infants seem to naturally realize the significance of faces and quickly learn to recognize the faces of their mothers, for example. Applying a simple pattern matching algorithm to this ability only makes the ability seem more mysterious. The appearance of a face changes often and for many reasons, including changes in mood, hair styling, lighting and more. Moreover, the person may be moving, and the angle at which a face is viewed is rarely the same. How does an infant come to recognize a particular face as the same one viewed on previous occasions? Indeed, how do we come to recognize things at all? Something more than a physical perceptual mechanism must be involved. Memory is surely involved. There must also be something – some kind of process – that fills in missing parts of an image or suggests that an image is sufficiently similar to one that is recalled to regard it as representing the same thing. This process suggests a kind of pattern matching logic. *We picture facts to ourselves*. Babies create internal representations of their mothers.

The logic of this process can quickly escape our control. We start with one external reality (a mother's face) and one internal reality (a baby's internally constructed image of that face). When considering how the infant recognizes that face as its mother, a third reality intrudes – a recalled image. When making the judgment that this external reality is one's mother, one produces an internal image, recalls prior images one associates with one's mother, decides that the internally constructed image is sufficiently similar to the accepted mother-images to be part of that collection, and finally concludes that the external reality is indeed one's mother – presumably it is also sufficiently similar to the internally constructed image. Whew. All that pattern matching is enough to make one cry.

It is a good thing that babies are not logical – they would never recognize their mothers if they were. Consider this. For X (the internally constructed image of mother) to be judged as *truly representative* of Y (the mother), there must exist a third thing Z (a previously constructed and stored internal representation of mother) that is *truly representative* of Y. But how did the infant come to the conclusion that Z was truly representative of mother? Hmmm. Presumably, on a prior encounter with the mother Y (which we are allowing to be the same Y for the sake of simplicity), the infant constructed an internal image Z (which we are allowing to be the same as the one recalled earlier for the sake of simplicity), compared it with another stored image (let's call it W – why ever not?) of mother that had been previously accepted as truly representative, realized that this one was sufficiently similar to belong to that collection, and thereby concluded that it was also truly representative of mother. Well, this *third mother regress* cannot be infinite since the baby was born at some point and only then started constructing internal pictures and collecting images.

Infinite regress arguments seem to lead nowhere, which is where we were headed with that analysis. It is somewhat reminiscent of Aristotle's unmoved mover problem. The problem with infinite causal sequences is getting them started (or stopped, depending on your point of view). *That* problem. All events have causes. Event Z is caused by Y which was caused by X which was caused by … and so on back to a much prior event situation and on to an endless sequence of

prior events and causes. The imagination handles that logic about as well as the pattern matching regress and usually concludes that there was a big bang or some other bursting out party to get things going. Happy birthday.

So, how does the baby come to recognize mother? The ability to recognize faces takes some *reflection* – or at least may at one time have taken some time for reflection and comparison and recall. In any case, understanding how we recognize faces requires some serious reflection on various human abilities, characteristics and tendencies. To emphasize the significance of reflection, I pause for this moment of reflection:

> And indeed there will be time
> For the yellow smoke that slides along the street,
> Rubbing its back upon the window-panes;
> There will be time, there will be time
> To prepare a face to meet the faces that you meet;
> There will be time to murder and create,
> And time for all the works and days of hands
> That lift and drop a question on your plate;
> Time for you and time for me,
> And time yet for a hundred indecisions,
> And for a hundred visions and revisions,
> Before the taking of a toast and tea.
>
> From T. S. Eliot's "The Love Song of J. Alfred Prufrock"

What was that question dropped on our plate? What was it that we were trying to understand? How we are able to recognize faces. Well, visual cues typically come bundled with other perceptual cues. Perhaps babies also smell their mothers; the reverse is certainly the case. There is the famous biblical story of Jacob and Rebecca deceiving the blind Isaac using the *smell* of Esau's clothes and the *feeling* of an arm disguised using goat skin to feel hairy and rough, like Esau's. While we might use several senses together to identify objects, we can nonetheless be misled. Descartes makes much of this possibility in his *Mediations on First Philosophy* – never trust a source that has misled you even once. If we followed such advice, we would suffer the same fate as those babies who never learn to recognize their mothers due to the third mother regress. Perhaps fewer politicians would get re-elected, though, if we decided not to trust a source that had even once misled us. There is almost always a silver lining to inquiry and investigation.

Well, it seems there is a need for some kind of explanation with regard to how we manage to build up an understanding of our surroundings and experiences out of these internal representations we construct. *We picture facts to ourselves*. Is it not remarkable that we are able to make sense of these pictures? Even more remarkable is how quickly an infant is able to automatically recognize a face, even one of those *early-morning-after-a-very-late-night* faces. Perhaps it takes an infant two or three times to develop an association of a face, and perhaps also a smell, a

sound and a touch, with mother, milk and such. Quickly the recognition process becomes highly automated and only a momentary glimpse is required. Once the pattern recognition process is established, it is highly resilient. What might this suggest about human reasoning?

The notion that we create internal representations to make sense of our experiences and surroundings is a fundamental tenet of a naturalistic epistemology that has roots in the philosophical works of David Hume and Immanuel Kant. In the 20th century, naturalistic epistemology became the basis for socio-constructivist approaches to education, although there is much confused discourse pertaining to constructivism in learning and instruction. As a tenet within naturalistic epistemology, the claim that we picture facts to ourselves is not a prescriptive claim – it does not tell the baby that it *should* create an internal picture of that face to see if it is mother and likely to bring comfort. We simply do, it seems, create internal representations of things. We do so naturally and without any prompting or guidance. We cannot stop creating these internal representations, and many will argue that the process continues even while we are sleeping. Ah, "to sleep, perchance to dream" … pass the rubbing alcohol … all this talk about epistemology is making my brain muscles ache.

> Half of the people can be part right all of the time,
> Some of the people can be all right part of the time.
> But all the people can't be all right all the time
> I think Abraham Lincoln said that.
> "I'll let you be in my dreams if I can be in yours,"
> I said that.
>
> From Bob Dylan's "Talking World War III Blues"

We create internal representations to make sense of our experiences, and then we use these representations to guide our actions and to structure our discussions with others. We realize that on occasion others may be viewing the same situation and engaging in a similar process of creating representations and sense making. What about these others? Might some of them be constructing internal representations that are sufficiently similar to mine to guide them to similar actions and conclusions? Half of them might say and do things similar to those that I would say or do. Hmmm. I suppose we need another distinction – that between internal and external representations, to which I have alluded already on several occasions. *We picture facts to ourselves*. These internal pictures are private and cannot be directly inspected or shared. We also create external representations of these internal pictures that are public and can be shared. These artifacts become part of the observable world and might also be worthy of investigation and consideration.

Ouch. Occam's razor just got stuck in my beard. Am I multiplying entities beyond necessity? We began with external realities (mothers) and internal representations (constructed internal images of mothers). We added more internal things – things stored in and recalled from memory. Now we are adding more external

things – human constructed representations to be used in talking about other external things as well as about those non-shareable, unobservable internal representations. Okay, it is a lot to keep up with, but perhaps it will explain how it is that we are able to build up an understanding of our experiences and surroundings and share that understanding with others. Perhaps. Perhaps these things are more of those basic building blocks of learning and instruction mentioned earlier.

Deconstructing Dylan and Reconstructing Constructivism

The title of this section is intended to get you to read this first introductory sentence, which is intended to get you to read the next. The previous sentence is not true. One can be paradoxical without contradicting oneself.

The thread that ties Gödel, Escher and Bach together for Hofstadter (1979) is self-reference. Escher creates paradoxical drawings by having one element of the picture connected with another which is connected to another that eventually connects back to the original – a visual form of self-reference. Bach's musical compositions often follow a pattern of self-reference such that a specific operation is performed on the previous part of the composition to create the next; as this pattern of modifying the previous part to get the next in a particular way is repeated, the composition returns surprisingly to its original form. Paradoxical outcomes may result from self-reference. Hofstadter uses self-reference to elaborate and explain Gödel's incompleteness theorem. Stated in non-technical terms, the incompleteness theorem postulates that in a formal system sufficiently powerful to generate all of the truths of integer arithmetic there are well-formed statements that are known to be true but which cannot be proven or refuted in that system. Even our most solid mathematical knowledge is inherently incomplete.

One such example of an *unprovable* truth is the claim that 'MU' is not a word in the formal language I call 'M-I-U'. The next section contains Hofstadter's (1979) MU puzzle along with an external representation of a problem-solving sequence followed by a similar puzzle that might be used to test transfer of learning.

The MU Puzzle

Given:

A) An artificial language with three letters in its alphabet: 'M', 'U', and 'I'
B) All strings or words in this language begin with and contain exactly one 'M'
C) Four rules to apply to existing strings of letters to generate new strings:
   1) A 'U' can be added to any string that ends in 'I' (MxI → MxIU)
   2) The entire string after the initial 'M' and be replicated and appended to generate a new string (Mx → Mxx)
   3) Two consecutive 'U's can be dropped (MxUUy → Mxy)

4) A 'U' can be substituted for three consecutive 'I's (MxIIIy → MxUy)

D) One initial string – namely 'MI'

Derive: 'MU'

Notes: The variables 'x' and 'y' represent any sequence of letters in M-I-U including the null set. In the derivation, show the source string, the rule, and the resultant string. The search for a derivation may be represented as a tree structure as shown in Figure 1.

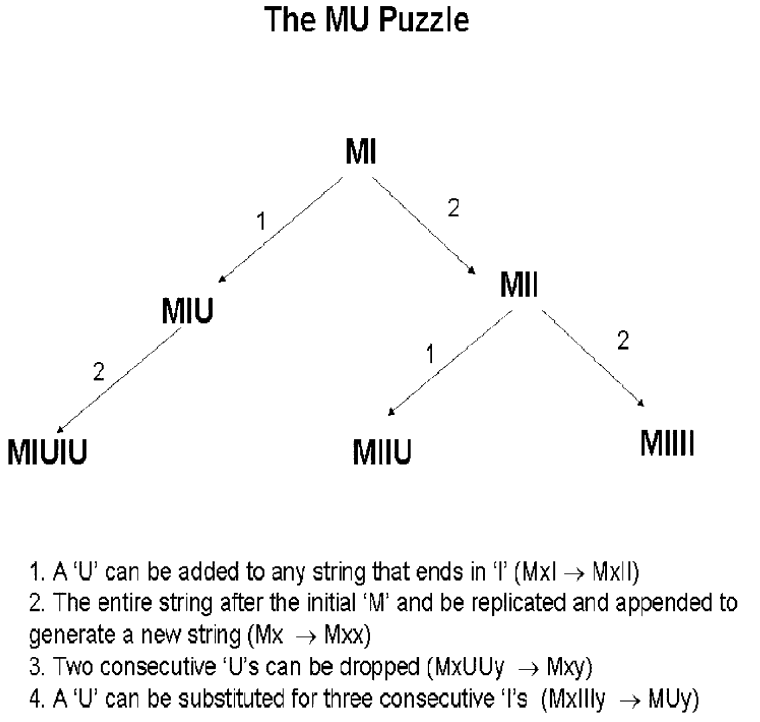

Fig. 1. The beginning of a derivation of MU.

A Different Puzzle?

Given:

- An artificial language with exactly five letters: M, E, Y, O, U
- The initial sequence: M E

- And six transformation rules (x and y are variables that stand for any sequence of letters including the null set)

1. If the sequence ends in E, a U can be added (M x E → M x E U)
2. The entire sequence following the initial letter can be replicated (M x → M x x; Y x → Y x x)
3. Two consecutive U's can be dropped (M x U U y → M x y ; Y x U U → Y x y)
4. Three consecutive E's can be changed into an U (M x E E E y → M x U y; Y x E E E → Y x U y)
5. An M can be changed into a Y (M x → Y x)
6. An O can be added after a Y (Y x → Y O x)

Derive: Y O U

You should know that 'MU' is not a word in the M-I-U language, but there is nothing in that language itself which can demonstrate that 'MU' is not among the infinite words that are in the language. A computer programmed to generate words in the 'M-I-U' language according to the four MIU rules and check at each step to see if 'MU' was generated would never terminate – that is an example of the halting problem (it might be better named the non-halting problem). It would be perverse to engage computers in such meaningless tasks – we have no such qualms with regard to people unfortunately. Is 'YOU' a word in the 'M-E-Y-O-U' language?

Language, Learning and Constructivism

I introduced those problems to get you thinking about reasoning that was difficult to explain in terms of prior experience and to help you appreciate the value of collaborative problem solving. I have discovered over the years that students reach the correct solution to those puzzles more often and more quickly when working in small groups of two or three. I am reminded of what Bob Dylan said in "Talking World War III Blues" and cited earlier:

> Half of the people can be part right all of the time,
> Some of the people can be all right part of the time.
> But all the people can't be all right all the time …

Of course I object to 'all' in the claim that "all the people can't be all right all the time," but this is a nice transition from the value of collaborative problem

solving to constructivism. Beware, I am beginning to apply some tension to the rope around your neck. This may hurt.

As Vygotsky (1978) and many others have noted, we do and can learn *with* as well as *from* others. Much learning involves language, although one can cite instances of learning that do not involve language. Language is socially constructed. Using language requires some general agreement on rules, recognition that certain statements are acceptable or not, and much more. Wittgenstein (1963) argues that there can be no such thing as a private language. The nature of language requires recognizable rules and shareable interpretations of utterances. Language is learned through interaction with others. Language mediates much of our thinking, and language is inherently a socially-based enterprise. For Wittgenstein, then, the meanings of words are dependent on their use in various social situations. One may use the phrase 'it's raining' for example to convey to a second person that it is time to pack the car and leave town due to an impending hurricane – this is not a weather update as the words stripped from the situation might suggest. It is conceivable that one could use that same phrase in many other ways. What is critical is the shared interpretation – the use within a particular community of language users – a language game. You may resist this thought so give it some time to settle in before proceeding to the next paragraph. There cannot be a completely private language. Repeat this 30 times and go back to the beginning of this note, being careful to follow all directions to the reader, of course.

A constructivist may claim that each individual perceives a reality and constructs a private, internal interpretation of that reality (Glasersfeld, 1987). This idea is not new. Immanuel Kant's *Critique of Pure Reason* was published in 1781. In that book Kant claimed that individuals construct interpretations of the world based on their experience. Kant went on to claim that language was in fact possible because people were inclined to interpret things, and then talk about them, in terms of commonly accepted and recognizable categories, such as space, time and causality. Where these *a priori* categories came from was not clear in Kant's account. While individuals might differ with regard to what item was in a particular place at a particular time and how it may have influenced other things and events, the discourse about those differences is possible just because we all recognize the basic categories (space, time, causality) and we construct similar kinds of interpretations. This is an important point. What we say about our experiences is mediated by language and language is a social enterprise.

Wittgenstein (1961) put it this way: *we picture facts to ourselves*. Is this not a marvelous ability – to picture facts to oneself – and to then represent one's interpretation of those facts to others – is it not amazing that we have such capabilities? (One is allowed to be repetitive when in the presence of such marvelous wonders; the repetition in this chapter is intentional; perhaps it is the third repetition that produces the desired effect.) Wittgenstein, like Kant, did not go on to conclude that the meaning was also internal and private. For Wittgenstein, meaning occurs within the context of language and use within a community of speakers.

Some constructivists, however, go on to say that meaning-making is a completely private enterprise (Glasersfeld, 1987). Each person interprets reality and no interpretation is better or more accurate or more acceptable than any other. Moreover, one person cannot ever see or experience or judge or evaluate what another person has constructed. Beware. The rope has now been sufficiently tightened.

Radical constructivism ends in *epistemological solipsism* [a new term you can use to recover the good favor of those you got to try to solve the MU puzzle for or with you]: the only world that I can know about is my world – that is what the radical constructivist concludes. This is a form of disguised nonsense. The epistemological solipsist may go on to conclude, even more radically, that the only world that exists is his or her world [actually, there could be no 'his or her' on this view as there is only one world – my world – ruling out the other alternative and much more]. Ontological solipsism ("I am the world" or "Only my world exists") may be more obviously confused than the epistemological variety, but neither is defensible. Why? Because to defend or even make such claims one is required to make use of language, and language can only be learned from others and used in ways that make sense, at least on many occasions, to others. The radical constructivist has taken away the possibility of language and meaningful communication. My sense is that it is best to allow such persons to continue in their silent worlds; time is better spent talking with the other half of the people who might be almost right part of the time.

Okay, there are two points to be made at this interlude. First, constructivism refers to a particular kind of epistemology – it falls into the general category of naturalistic epistemologies in contrast with deductive epistemologies (a philosophical distinction you need not remember except for the test to be administered to all those who successfully complete this chapter following all the directions provided to readers). There are two versions of constructivism – radical constructivism and social constructivism, as others have mentioned; the latter is the kind that Vygotsky and Wittgenstein and many others, including Immanuel Kant and Robert Gagné would recognize as legitimate and meaningful. Yes, you heard me correctly. Gagné regarded himself as a constructivist in the sense just explained; he recognized constructivism as a reasonable epistemological perspective and accepted that position readily. He detested the discourse with regard to constructivism in the instructional design and educational technology communities, however, and refused to dignify the positions of many so-called constructivists with comments. Gagné believed that the so-called instructivist-constructivist distinction was confused and illegitimate.

The second point I wish to make is more general – one ought to pay careful attention to the implications of what one says. In deliberations about anchored instruction, situated cognition, and cognitive apprenticeship. there are often stimulating and animated discussions about the design of instruction and transfer of learning. Consider the following statements for example:

1. Learning activities ought to be designed so as to be meaningful.
2. Learning activities ought to be designed so as to be authentic.

3. The first can be linked in a reasonably clear chain of reasoning, from a naturalistic epistemology such as social constructivism (i.e., a philosophical foundation on which there is very broad general agreement) to a cognitive psychology of learning and finally to principles to guide the design of instruction. Design activities that will engage learners in meaningful ways such that learners will be interested, able to activate relevant prior knowledge, interpret new phenomena within the context of things already understood, explain and anticipate likely outcomes of these phenomena, and so on. Of course there can be measurable outcomes that will help instructors and designers determine the efficacy of efforts to support learning. In short, the first statement can be interpreted in a way that makes it a testable hypothesis. It would not be surprising to find empirical evidence to support the first claim since it is now quite well established that the more time that learners spend on tasks the more likely it is that they will acquire intended competencies. Meaningful learning activities tend to keep learners engaged, resulting in more time spent on task. Perhaps more importantly, what learners regard as meaningful are things that can in some way be related (a) to things they already understand, and (b) to things they want to understand.
4. The second statement goes beyond this claim by suggesting that activities that are meaningful will be authentic in the sense that they represent actual tasks to be encountered outside the learning situation. While this may be a testable hypothesis, it is rarely tested. If it were tested, it might prove quite limiting. Moreover, it does not address learning hierarchies – the important notion of mastering simpler tasks and problem solving activities and then going on to more complex and challenging tasks and problems. The second claim buries the notion of being related to something already understood. Rather, it becomes a mantra for those who advocate a particular approach to learning and instruction – namely use only actual tasks in learning activities. One ought not confuse advocacy with scientific inquiry. I regard this as a fundamental point of departure, but I know that many advocates of post-modernism disagree with this position. I know that I am old fashioned – older than dirt, so to speak. I regard it as an essential part of my job as a teacher to train learners' ears so that they will become insightful members of a community of speakers of a language that can also be called M-I-U – Mastering Instruction for Understanding. Train your ears to hear the difference between 'meaningful' and 'authentic' – ask authors and interlocuters what is meant by such terms, what positions associated with these terms imply, what has been assumed, and what evidence exists or might exist to confirm or refute such claims. If no evidence will convince a person that a claim is wrong, then you can conclude that this person is not open to scientific inquiry and is advocating a position; you may or may not agree with the position being advocated, but you ought not confuse advocacy with inquiry.
   We picture facts to ourselves (Wittgenstein, 1961). Try picturing these (Spector, n. d.):

1. It would be a remarkable coincidence if the limits of my imagination happened to coincide with the limits of reality.
2. We can say more than we can know.
3. We can know more than we can say.

What we cannot speak about we must pass over in silence (Wittgenstein, 1961).

Success in this enterprise requires having mastered conservation. I know that I have mastered conservation because when I take a glass half full of water and pour it into a similar glass, the new glass into which the water is poured will be half empty.

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