"Earth Science as a Vehicle for Illuminating the Boundary between the Known and the Unknown"

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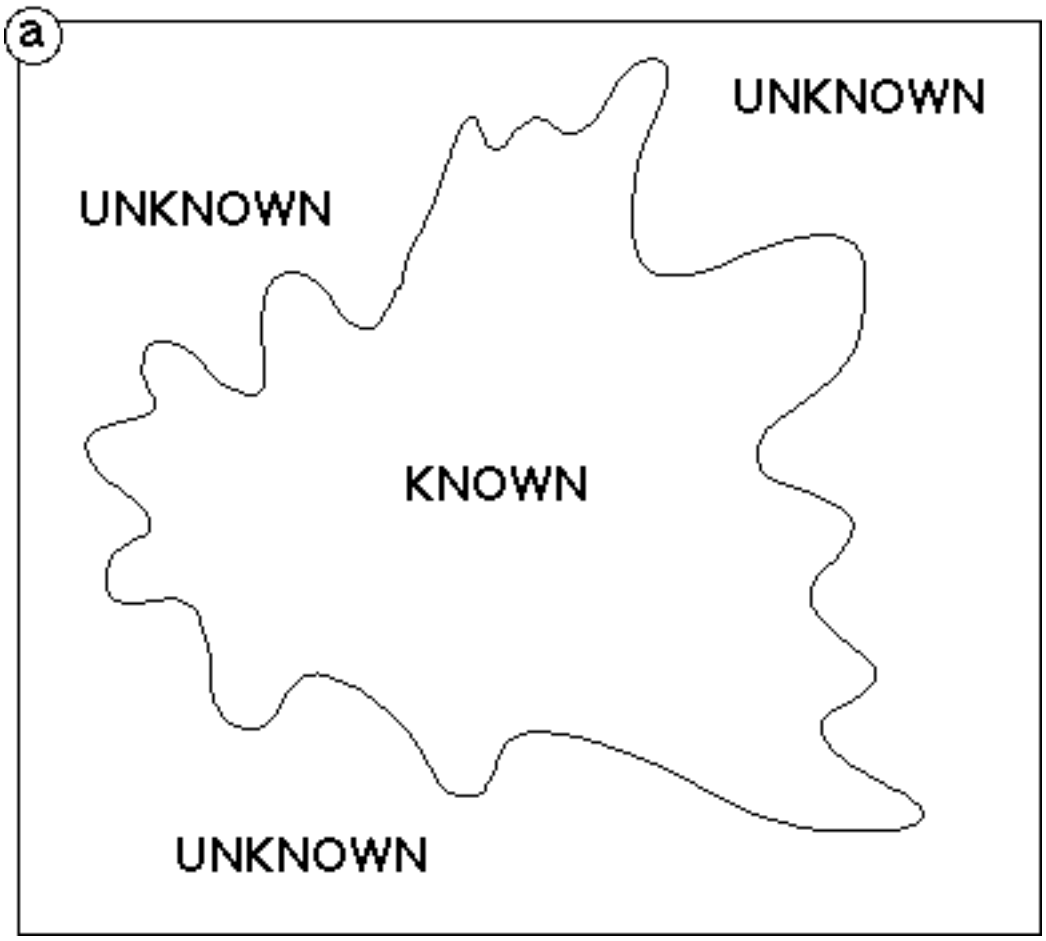
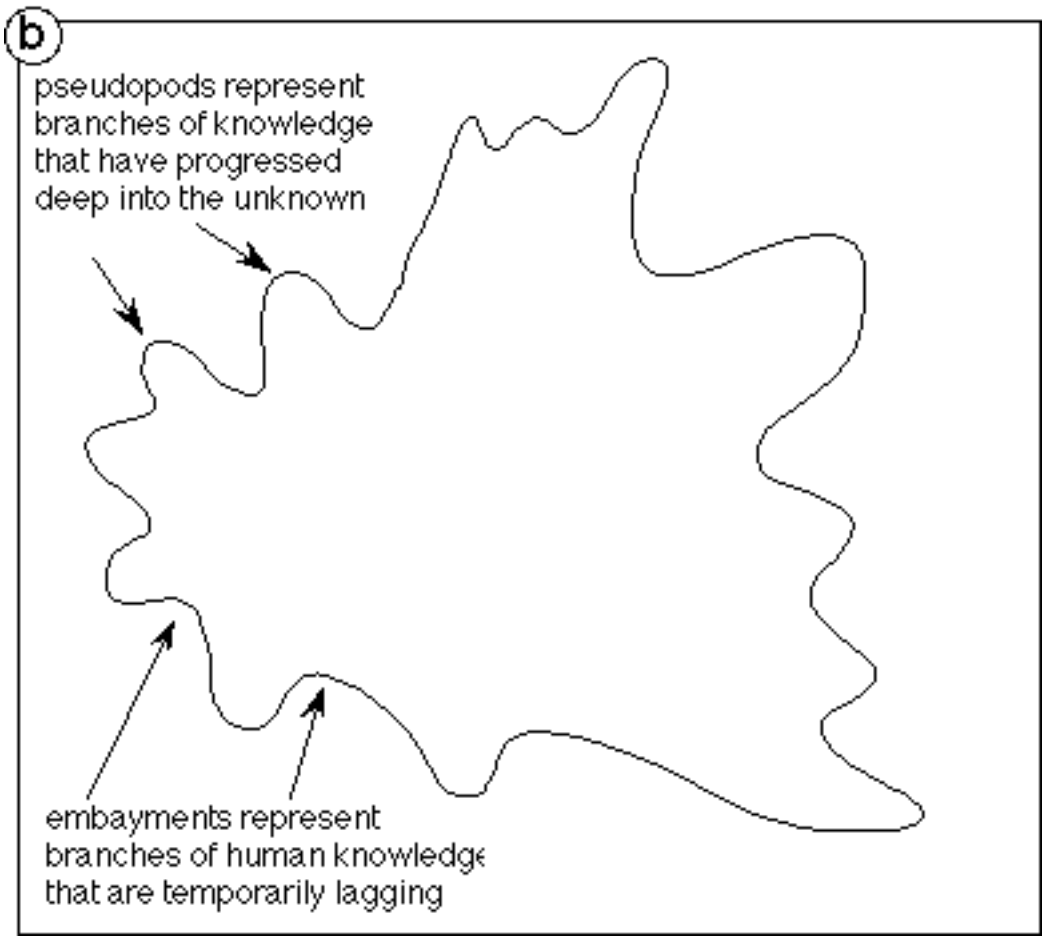
A pervasive theme throughout my recent conversations about science education has been "Sciencing" as a verb, "science" as a process rather than as a collection of facts. But in truth "science" is not a single process; it is a collection of interwoven processes. To help our students adopt this alternative perception of science, we obviously need to help them understand and experience the processes of hypothesis formation, of experimental design, of collecting and analyzing and interpreting data. I think that in recent years, the teaching profession has made great strides at helping students to understand those processes. In this article, though, I'm going to focus on another profound aspect of the "process" of science, an aspect that has not been emphasized as much: the process of finding a solvable question. Of all the infinite number of questions that can be asked about the earth, only a small subset are solvable at any given moment in human intellectual history. A solvable question is, first of all, a question that hasn't already been solved, and secondly, a question that can be solved with techniques and understandings that exist or that can be developed.

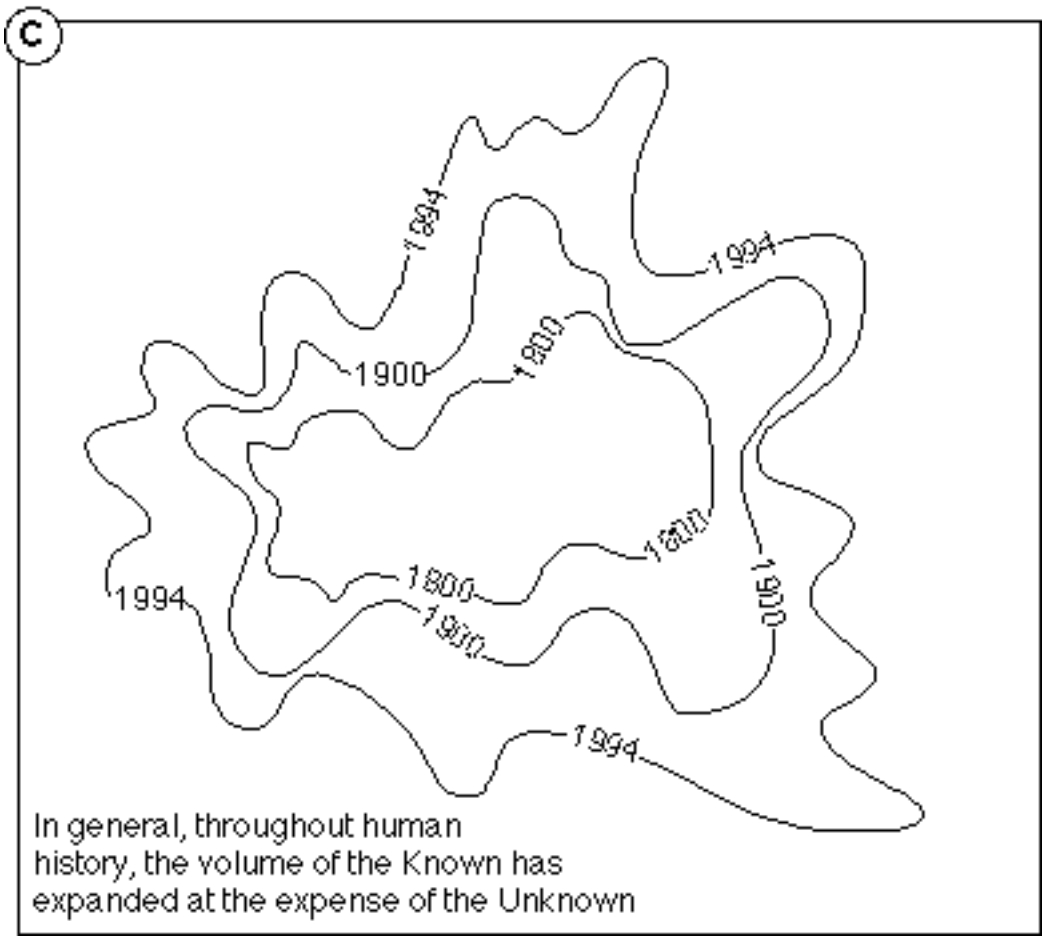
It turns out that this special set of solvable questions cluster together. The place where they cluster constitutes the boundary between the Known and the Unknown. To me, human knowledge seems like an ameboid shape (figure a).



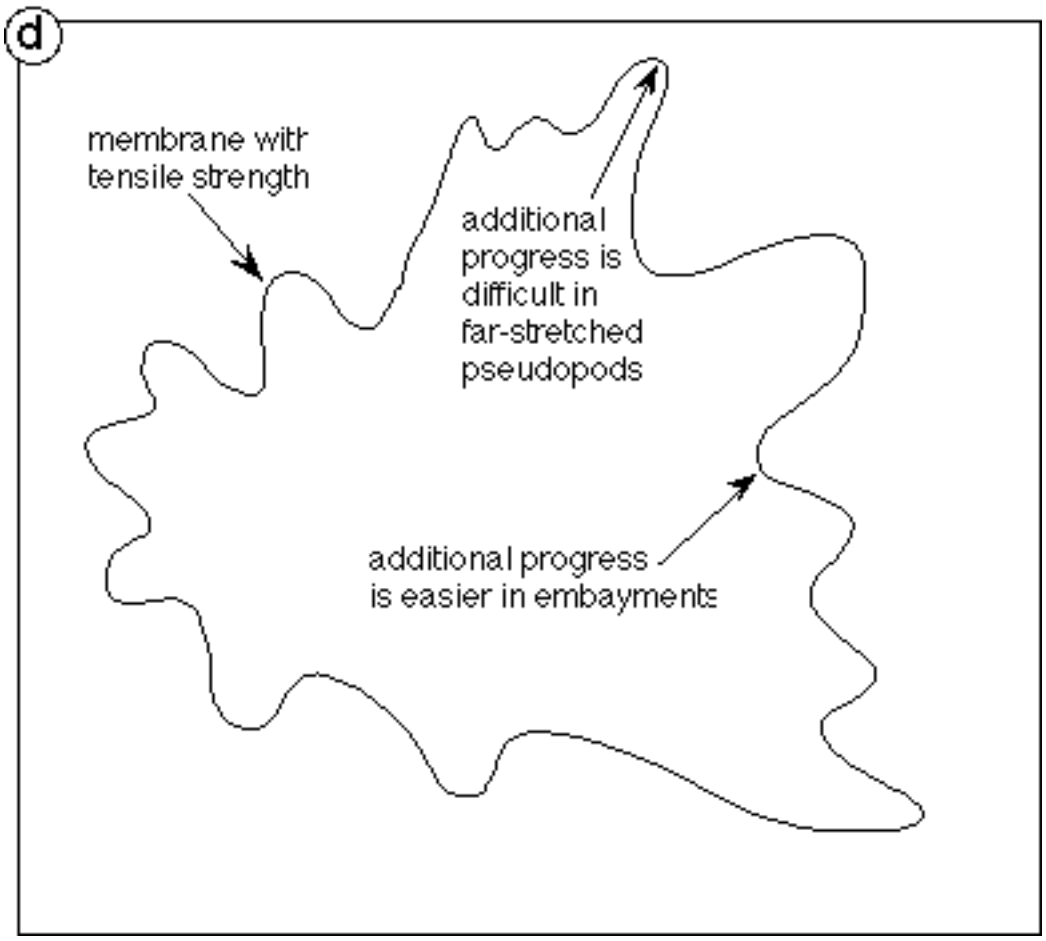
Inside is everything that is known or understood by human beings, by at least by one human being, somewhere in the world. Outside is every thing that is not known at all, by any human being, anywhere. The pseudopods of the amoeba represent branches of human knowledge that have progressed quite far into the unknown (figure b).



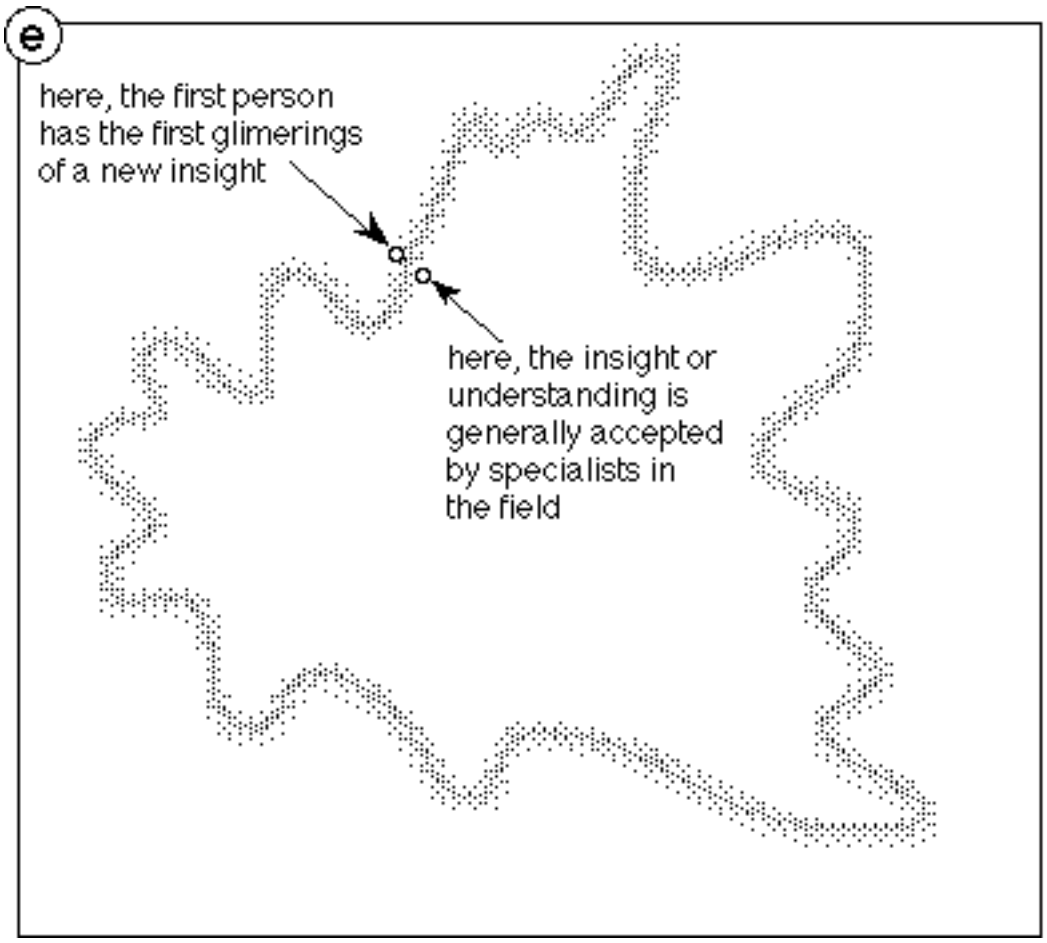
The embayments are branches of human knowledge that are temporarily lagging behind adjacent lines of inquiry. In general, throughout human history, the ameba has grown--the volume of the Known has expanded at the expense of the Unknown (figure c).



During occasional dark ages of human history, the ameba contracted as books were burned or intellectuals were persecuted. I have drawn the amoeba in two-dimensions. But in truth must be a multidimensional shape, a shape intricate enough to represent every line of inquiry in every branch of knowledge. I envision this boundary as having some tensile strength, like a stretchy membrane (figure d).

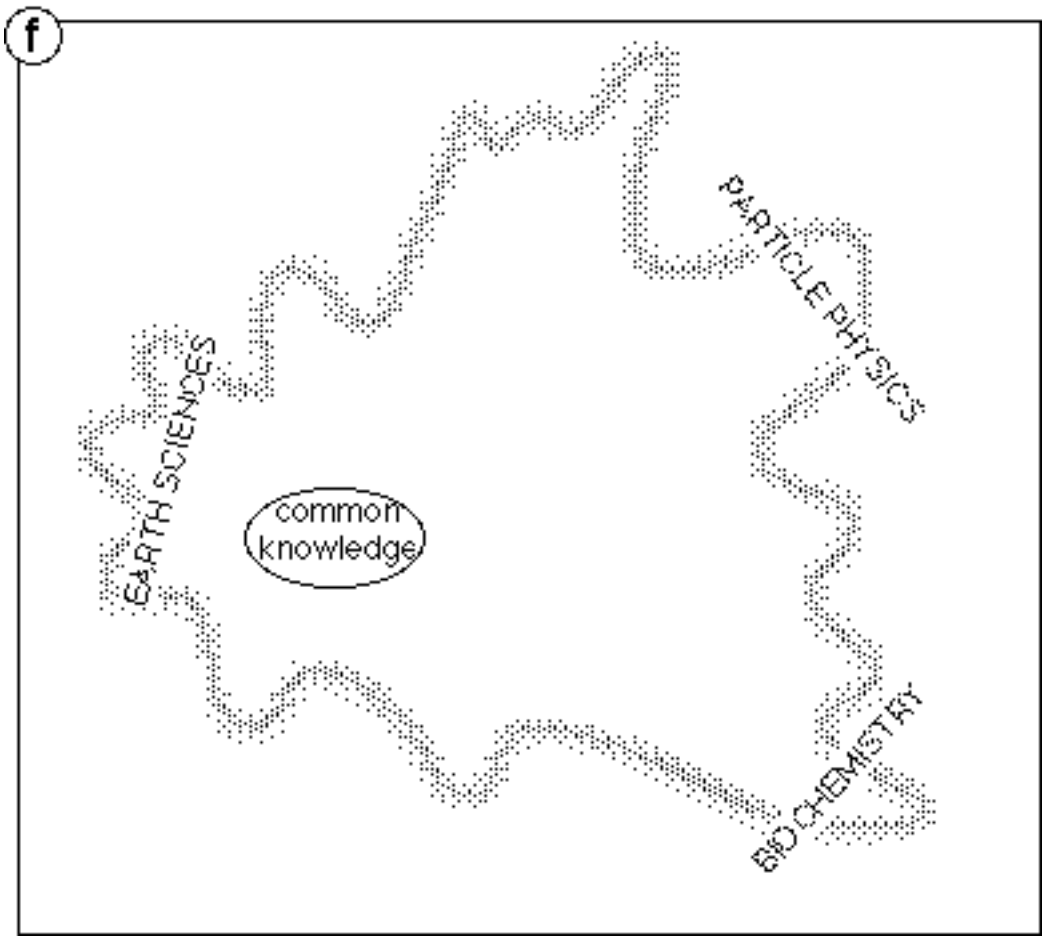


The stretchiness inhibits growth of the ameba -- energy must be expended to push back the frontier between the known and the unknown. As a given pseudopod, a given line of inquiry, is pushed farther and farther into the unknown, the bounding membrane is locally stretched more and more drastically, and the energy required to expand the domain of the known in that particular direction rises rapidly. The easiest advances occur in the embayments, in those branches of knowledge that lie between the farthest stretched pseudopods. I have drawn the boundary between the known and the unknown as a solid line, but in truth it should be drawn as a zone of finite thickness (figure e), where the thickness represents the transition from the point where the first human being on earth has the first glimmerings of comprehension of anew truth, to the point where the understanding is generally shared by specialists in that branch of knowledge.



Scientists live and work within this boundary; we dance on the interface between the Known and the Unknown. Students bump into this boundary occasionally, but generally they are only dimly aware of its existence or location, even when they are standing on it.

Within that larger volume representing all knowledge of all people everywhere on earth, one can draw a smaller volume representing "common knowledge"--the things that most people know, from everyday experience, from television, from newspapers, from movies, from popular literature, and so forth (figure f).



Note carefully that the volume of common knowledge is not evenly centered within the volume of all knowledge. Common knowledge is closer to the boundary between the known and the unknown in some branches of human knowledge than in other branches of human knowledge. And in particular, common knowledge is close to the boundary between the Known and the Unknown in Earth Science.

In a typical high school or lower-level college math course, everything the student studies has been known for at least a century. In a typical high school or introductory college chemistry course, almost everything the student studies has been known for at least half a century. A Chemistry or Physics major in college typically has to persevere through three or four years of coursework before he or she can even begin to understand the questions on the cutting edge of the field, let alone understand the answers. The boundary between the Known and the Unknown in chemistry and physics is very far from the field of common knowledge.

Earth Science is not like that. In Earth Science, the boundary between the known and the unknown is close-by; it's very accessible, very understandable to the newest students on the very first day of their very first Earth Science class. Why are there mountains over here, but not over there? Will there be another ice age, and if so, when? Why did the dinosaurs go extinct? Why are the oceans salty? Why is there so much oil in Saudi Arabia, and none in Rockland county? Where do diamonds come from? Where did the moon come from? Why does it snow a lot in some years and not very much in other years? These questions are at or near the frontiers of research in Earth Science. Yet these questions can be understood by any student; indeed these questions can be conceived

and posed by any student.

Imagine or recall a circumstance in which a beginning student posed a seemingly simple question about the earth, and a teacher answered, truthfully, "nobody knows; nobody in the world knows the answer to that question." I think that something really important has just happened. That student has just bumped into the boundary between the Known and the Unknown; that student has found his way or her way to the place where science begins. From that starting point, and while remaining entirely within the realm of concepts and questions that students understand, we can explore where exactly the boundary lies: "this is understood, this is sort of understood, this is not understood at all."

Here's another way to think about this idea. Imagine now that we sit physically rather than conceptually within the amoeboid shape of human knowledge. Imagine that I am holding a flashlight, which represents my personal knowledge, plus my communications skills, plus my energy and enthusiasm and motivation, plus my instructional materials, in other words the sum of all the resources I have available to convey insight and understanding to my students. If I shine my light in the direction of Earth Science knowledge, it's easy for me to reach the frontiers of knowledge -- the boundary between the Known and the Unknown in Earth Sciences is close to the field of common knowledge where my students and I begin our exploration. On the other hand, if I shine my light in the direction of Particle Physics, only the feeblest illumination reaches the frontiers of knowledge. I have the same light, representing the same depth of personal knowledge, the same communications skills, the same energy, the same quality of instructional materials, the same resources in total. But the distance between our starting point in the field of common knowledge and the frontier of Particle Physics is too large -- my light doesn't reach. Similarly, if I shine my light in the Biochemistry direction, it's still pretty dark over there at the frontier of knowledge; the boundary between the known and the unknown can only be dimly perceived.

In conclusion, I feel that we, as teachers of Earth Sciences, have a special opportunity within the grand scheme of science education, an opportunity that is less easily available to our colleagues teaching in most branches of science and math -- we can illuminate the boundary between the Known and the Unknown.