Geospatial Data-Information-Knowledge-Wisdom Hierarchy

Robert F. Austin, PhD, GISP*

Abstract

Knowledge is developed through one or more mechanisms, subject to certain constraints inherent to any logical system. Knowledge and the method by which that knowledge is organized influence subsequent inquiry and further knowledge development. The higher goal of knowledge development and organization is the attainment of wisdom, which may be defined as the ability to apply relevant knowledge to situations different from those in which the original knowledge was developed. The Data-Information-Knowledge-Wisdom (DIKW) knowledge pyramid provides a way of clarifying these relationships to further this goal. This knowledge pyramid has utility in the consideration and organization of geospatial knowledge.

The Blank Slate

The term *tabula rasa* ("blank slate") refers to the belief that people are born without knowledge and that their knowledge is gained through experience and perception. The concept describes how pieces of data, such as observations, sights, sounds, smells, are received and written on a blank slate and, subsequently, how those data are manipulated to create knowledge. In the debate over nature versus nurture (that is, the question of which is the primary determinant of human behavior) the concept of *tabula rasa* argues that the answer is nurture.

Although Aristotle wrote about the blank slate in *On the Soul*, it appears that the concept was not developed formally for more than 1,000 years. The Persian philosopher Ibn Sina (Avicenna) defended the theory of *tabula rasa* in the 11th century. Ibn Sina argued that the "human intellect at birth is rather like a *tabula rasa*, a pure potentiality that is actualized through education and comes to know" and that knowledge is gained through "empirical familiarity with objects in this world from which one abstracts universal concepts." (Rizvi, 2006) This concept was later elaborated and popularized in the first Arabic novel *Hayy Ibn Yaqzan*, written by Ibn Tufail (Abubacer).

With Edward Pococke the Younger's publication in 1671 of a Latin translation of Ibn Tufail's novel as *Philosophus Autodidactus*, and Ockley's (1708) subsequent translation into English under the title *The Improvement of Human Reason*, the concept returned to the attention of Europe. Among the individuals influenced by this publication was the philosopher John Locke (1632-1704), whose "theory of mind" drew heavily upon the concept of the blank slate. "Contrary to pre-existing Cartesian or Christian philosophy, he maintained that we are born without innate ideas, and that knowledge is instead determined only by experience derived from sense perception" (Baird and Kaufmann, 2008). Locke's thoughts, in turn, informed the work of George Berkeley (1685-1753), David Hume (1711-1776) and Immanuel Kant (1724-1804) in what has been called the "classic sequence of the theory of knowledge."

The Irish philosopher George Berkeley created and promoted a theory he called "immaterialism," later referred to as "subjective idealism." This theory argues that we can only know direct sensations or perceptions and that ideas are dependent upon being perceived by minds for their very existence, a belief that became immortalized in his statement, *"Esse est percipi"* ("To be is to be perceived").

Berkeley argued that objects ceased to exist when there was nobody present to perceive them. In *A Treatise Concerning the Principles of Human Knowledge,* he proposed (Berkeley, 1734, section 45), "But, say you, surely there is nothing easier than for me to imagine trees, for instance, in a park... and nobody by to perceive them... The objects of sense exist only when they are perceived; the trees therefore are in the garden... no longer than while there is somebody by to perceive them." This is, in effect, an answer in the negative to the question, "If a tree falls down in the woods and no one is around to hear it, does it make a sound?"[1]

From Berkeley's vantage point, the metaphysical answer is that no, the tree does not make a sound if no one is there to witness it falling. Indeed the act of making a sound isn't even an issue, because the tree itself ceases to exist if no one is there to witness it.

The common sense answer to this question is, of course, that it must make a sound because we know that a tree falling makes noise regardless of whether anyone is in the vicinity. Thus, in an answer from a fictional future, the character of Spock from the *Star Trek* television series famously said, “Lieutenant, I am half-Vulcanian. Vulcanians do not speculate. I speak from pure logic. If I let go of a hammer on a planet that has a positive gravity, I need not see it fall to know that it has in fact fallen” (Mankiewicz and Carabatsos, 1966).

Several points may be drawn from this dialogue, one of which is relevant to the present discussion. The character states that he speaks “from pure logic.” In this case, we may assume that Spock intends the phrase “pure logic” to mean the application of deductive reasoning. Deductive reasoning depends on the application of laws, rules or widely accepted principles and is sometimes referred to as an argument that moves from the general to the specific. The alternative form of logic is inductive reasoning, which depends on observations that are subjected to logical analysis, that is, an argument that moves from the specific to the general.

The character Spock acknowledges that he is not speaking about something he personally has observed or measured (data), but rather about a law that was derived, by one or more other people, from multiple observations (that is, data collected prior to the event). The phrase “I need not see it fall to know that it has in fact fallen” summarizes an expectation that accumulated evidence from past observations is an accurate predictor of future behavior. This phrase, essentially an article of faith, expresses an axiom in the physics of Star Trek. Although any inductive argument can also be expressed deductively and any deductive argument can also be expressed inductively, the distinction is important because it affects the way in which support is offered for the argument.

Even if Spock’s statement is an accurate description of an outcome, it does not constitute or provide data. It does not describe the mass of the hammer, the mass of the planet, the density of the atmosphere, the speed of travel or the location of the event (for example, atmospheric or submarine). It also does not specify the direction and velocity of prevailing winds or currents, the elevation of the hammer when released or other variables that would affect the position of the hammer when it fell, the volume of the sound on impact, the compression of the surface impacted or similar effects of the fall. Indeed, such variability is implicit in Spock’s use of the phrase "*a* positive gravity," which implies the existence not only of negative gravity but also of multiple types of positive gravity with varying characteristics and effects.

Knowledge of the variables and their effects would require observation and measurement. Spock may "need not see it fall to know that it has in fact fallen," but he would need to see it fall (or use observational sensors) to measure and record its effects to obtain data. Those data would be susceptible to further inductive analysis.[2]

Returning to our central theme, there does not appear to be evidence that Berkeley personally was the source of the "tree falling" question. The first publication appears to have been in 1883, when the magazine *The Chautauquan* (1881, p 543) published the question, "If a tree were to fall on an island where there were no human beings would there be any sound?" The authors answered, "No. Sound is the sensation excited in the ear when the air or other medium is set in motion."

Another periodical of that era provided confirmation and a more detailed answer (*Scientific American*, 1984, p 218) "Sound is vibration, transmitted to our senses through the mechanism of the ear, and recognized as sound only at our nerve centers. The falling of the tree or any other disturbance will produce vibration of the air. If there be no ears to hear, there will be no sound."

The production of sound requires three things: a source, a medium and a receiver. The source creates a series of traveling waves that vary in frequency and amplitude. These waves are mechanical waves that propagate through solid, liquid and gaseous media. The receiver collects and reacts to these waves and processes them. In the absence of a source, there is no reason to ask if there is a sound. In the vacuum of outer space, there is no medium to serve as a means of propagation and therefore there is no sound. In the absence of a receiver, a falling tree only produces a series of waves that travel through the air without collection. In this case, it is not a question of the absence of sound but rather the absence of awareness of the sound. All three components of sound production are required.

The philosopher Richard Rorty (1989, p 5) has generalized this problem:

> *Truth cannot be out there - cannot exist independently of the human mind - because sentences cannot so exist, or be out there. The world is out there, but descriptions of the world are not. Only descriptions of the world can be true or false. The world on its own - unaided by the describing activities of humans - cannot.*

Accurate observations are the basis for accurate descriptions. This is a key insight that points to the role of data in building information: observations are necessary to write upon the blank slate.

There is one *caveat* related to the act of observation. Werner Heisenberg made several fundamental contributions to the field of physics, for which he received the Nobel Prize in 1932. Perhaps his most widely known contribution was the *uncertainty principle,* which states that:

> *Certain pairs of physical properties, like position and momentum, cannot both be known to arbitrary precision. That is, the more precisely one property is known, the less precisely the other can be known. This statement has been interpreted in two different ways. According to Heisenberg, its meaning is that it is impossible to determine simultaneously both the position and velocity of an electron or any other particle with any degree of accuracy or certainty. According to others … this is not a statement about the limitations of a researcher's ability to measure particular quantities of a system, but it is a statement about the nature of the system itself as described by the equations of quantum mechanics.* ("Uncertainty Principle," n.d.)

Significantly, Heisenberg did not focus exclusively on the mathematics of quantum mechanics. He was primarily concerned with establishing that uncertainty is actually a general property of the world and that it is physically impossible to measure the position (vector) and momentum of a particle simultaneously to a precision better than that allowed by quantum mechanics.[3] The argument remains unresolved. However, observers must recognize the possible consequences for their observations.

In summary, data must be written on the *tabula rasa* and manipulated in some way to produce knowledge. The next question we must consider is "how data are written."

Writing on the Blank Slate

The *tabular rasa* can be written upon in one of four ways: 1) through observation, 2) through logic, 3) through testimony and 4) through revelation. Three of these methods have been demonstrated by example already in this article.

Observations may be made by one or more agents or actors by means of their own senses or may be made by sensing devices, used locally or remotely, that extend their senses in time, space or sensitivity. I may see a buffalo run and know that it is capable of running. I may use a stop watch to measure the time it takes for a buffalo to travel a specific distance and calculate the speed at which the buffalo was running, extending my observational ability to include measurements that I cannot perform accurately without instrumentation (for example, time and distance). Alternatively, I can set up an experiment that incorporates a camera, a triggering mechanism and related recording equipment to observe an event in my absence.

The question of "what to observe" is defined by the assumptions of the observer, a phenomenon termed by some writers as *observer bias*, as well as by concern for the effects of observation discussed previously. For example, if I wish to measure the speed at which a buffalo runs, I could measure the distance traveled and the time spent in traveling that distance and then calculate the velocity of the buffalo. However, if I wish to determine the impact of a collision of the buffalo with a fence, I would also need to measure the mass of the buffalo to determine the momentum of the running buffalo. Further, I would need to measure or calculate the crash resistance of the fence.

In summary, if I wish to study the travels of a buffalo, certain data must be obtained. However, if I wish to study the effects of a buffalo's travels, additional data are required. The selection of a topic for study may be iterative: having studied the speed of a moving buffalo, I then may decide that the effects of the travel should be examined. This would be an example of the extraction of information from data. In this present example, this process may lead to questions about fence construction methods and materials, the seasonal impact of food and water supplies on buffalo travels and the effects of buffalo reproduction rates on the demand for fence building materials.

The selection of the original question and collection of data designed to answer that question are the prerogative of the researcher. For this reason, observers often are asked to describe the assumptions leading to their work. This allows others to assess the validity (and biases) of the observations and the applicability of the observations to other areas of inquiry.

Logic, the second method of data acquisition, can involve inductive reasoning or deductive reasoning. Inductive reasoning makes use of source data acquired through other means and applies rules of reason to infer or extrapolate additional data or information. Modeling is a form of inductive logic, in that certain data otherwise acquired are used to build a model of behavior at a different scale or under differing circumstances.

Deductive reasoning, as noted previously, depends on the application of laws, rules or widely accepted principles. Such laws, rules and principles may have been based on the direct analysis of data (that is, may themselves be the product of inductive reasoning) or may be derivative in the sense that they have been extracted from previous deductions. Ultimately, deductive reasoning that has the physical world as its object must depend on some set of data, albeit data whose observation may have taken place far from current considerations.

Information acquired through logic cannot be "better" than the data (or information) upon which it is based. For example, certain remains of the genus *Homo* were found in or near Liang Bua cave on the island of Flores in Indonesia in 2003. Based on their examination of the partial remains of eight individuals, one group of scholars inferred that they represented a new species, which they named *Homo floresiensis*. (Brown *et al*, 2004 and Morwood *et al*, 2004) This finding was supported by cladistic analysis by a second group of researchers (Argue et al, 2009). A third group of scholars interpreted the same collection of remains as indicative of microcephaly while a fourth group suggested endemic cretinism and a fifth group suggested Laron syndrome (also known as Laron-type dwarfism). These inferences, based on partial remains from eight specimens, reflected the limitations posed by the available data. The lack of sufficient data placed confidence limits on our logical analyses. The addition of more data may influence the observers to revise or refine their analysis in the future.

Another example is offered by the phenomenon of Lysenkoism, or Lysenko-Michurinism in the Soviet Union in the 1920s. Trofim Denisovich Lysenko was the director of the Lenin All-Union Institute of Agricultural Sciences. Lysenkoism denotes the biological inheritance principle to which Lysenko subscribed, as derived from theories of the inheritability of acquired characteristics first espoused by Jean-Baptiste Lamarck and later given specific form by Ivan Vladimirovich Michurin.

In essence, Lysenkoism expresses the notion that an organism can pass on to its offspring one or more characteristics that it has acquired during its lifetime. In this regard, Lysenko's opinions about genetics differed significantly from the work of the Moravian scientist and Friar Gregor Mendel and the general thinking of Charles Darwin and Alfred Wallace. However, it did fit well within the Stalinist political environment in which Lysenko lived.

> *Following the disastrous collectivization efforts of the late 1920s, one of USSR's greatest agricultural problems during the 1930s was that many peasants were thoroughly unhappy with the collectivization. Lysenko's 'new' methods were seen as a way to make peasants feel positively involved in an 'agricultural revolution'. The party officials believed that peasants planting grain - for whatever reason - was a step in the right direction and a step away from the days when peasants would destroy grain to keep it from the Soviet government. Academic geneticists could not hope to provide such simple and immediately tangible results, and so were seen as politically less useful than the charlatanism of Lysenko.* ("Lysenkoism," n.d.)

Although Lamarck's interpretation and logical deduction may have seemed reasonable at the time that he proposed the inheritance of acquired characteristics, it quickly fell from academic favor in the face of the evidence gathered by Wallace, Darwin and a host of 19^{th} century geologists. The perpetuation of the Lamarck's deduction by Michurin demonstrates the importance of adjusting previous inferences in response to the collection of new data. Michurin and Lysenko's refusal to adjust their interpretations resulted in widespread suffering not only among the farmers whose actions were driven by flawed policy but also among researchers whose studies were diverted from experiments that are more productive. The number of related deaths due to starvation is an open but vigorous discussion.

A third example of logical analysis as a method of data acquisition has direct relevance for geographic research. In his analysis of the application of classification principles to regional systems, Grigg (1965, p. 469), citing Simpson (1961, p. 2) notes:

> *The purpose of classification, then, is to give order to the objects studied. Without classification, it would be impossible to:*
> *1) Give name to things,*
> *2) To transmit information,*
> *3) To make inductive generalizations.*

Grigg (1965, p. 466) observed "in classification objects are grouped on the basis of *properties* they have in common," in distinction to the similar procedure known as logical division, in which an initial class, or universe, is "divided into sub-classes on the basis of some principle (p. 468)." In either case, of course, we have returned to the question of "what to observe." In this regard, Grigg (1965, p. 466) notes the important distinction between "differentiating characteristics" and "accessory characteristics," observing "if the differentiating characteristic is carefully chosen, then other properties [i.e., the accessory characteristics] of the individuals will be found to change as the differentiating characteristic changes."

The third of the purposes cited by Grigg - to make inductive generalizations - underlies a fundamental tool in geospatial analysis: the concept of the region.

> *Perhaps the most important purpose of classification systems is to permit inductive generalizations to be made about the objects studied. Areal classification, or regionalization, serves a similar purpose. Many generalizations in geography arise from the comparison of two different regional systems; thus, for example, if in any one country an areal classification on the basis of soil type is compared with a classification according to land use, then a number of generalizations about the relationships between the two may be inferred.* Grigg (1965, p. 470)

The notion that regions "exist as real entities" and "there could be a correct regional system" has been largely abandoned (Grigg, 1965, pp. 470-1, citing Hartshorne, 1939). Nevertheless,

> *even among those who recognize that regional systems are not a classification of entities that exist in nature there is still a tendency to forget that lines on a map are rarely real and that any given classification or regional system is but one way of looking at the world.* (Grigg, 1965, p. 471)

The regions we define, the analysis we perform using those regions and the conclusions we reach from that analysis are fundamentally constrained by the choice of the data that is, or has been, collected and by the quality of that data.

Testimony, the third method of writing on the blank tablet, describes knowledge that is accepted based on assertions or statements by other people. To consider testimony as knowledge would seem to be at odds with the fundamental principles of science and with the orientation of such institutions as the Royal Society of London for the Improvement of Natural Knowledge, whose motto is *Nullius in verba* ("On the words of no one"). Nevertheless, it is unquestionably a method that had been used widely.

Testimony based on observation is subject to the phenomenon of observer bias, as well as the biases of the attester. Testimony based on logic may also be constrained by the quality of the observations on which the logic is based. Analyses and information based on a reference to authority would fall into the category of testimony. An example of information based on a reference to authority would be the Roman Catholic Church's classical assertion of the validity of geocentrism as opposed to heliocentrism. Closer chronologically, the first five paragraphs of this essay (and several other paragraphs scattered about) constitute testimony as do most exercises in pedagogy (an exception being the "Socratic dialogue").

Particularly in the early days of global exploration, testimony was often the only source of information about remote areas. However, over time, travelers' stories of krakens, dragons and mermaids were replaced by scientific studies of giant squids, crocodiles and dugongs. At present, data dependent on testimony is considered by many scholars to be of a lower quality than direct observation.

Consider the contemporary discussions of the nuclear fusion of atoms at conditions close to room temperatures, known colloquially as *cold fusion*. In 1989, two researchers, Martin Fleischmann and Stanley Pons, reported production of fusion in a tabletop environment. Others researchers were unable to reproduce these results experimentally. Lacking access to the data allegedly generated by these experiments, researchers also could not reproduce the results inferentially.

Analysts were compelled to evaluate claims based on the testimony of the original researchers, claims that – lacking evidence - ultimately were rejected by the scientific community.[4]

“Faith” and “belief” are not appropriate bases for the acquisition of data. Galileo Galilei noted the “worthlessness of authority in deciding any scientific question” (Cohen, 1985, p. 142). The naturalist and philosopher John Ray (1691) expressed a similar opinion: “Let it not suffice to be book-learned, to read what others have written and to take upon trust more falsehood than truth, but let us ourselves examine things as we have opportunity, and converse with Nature as well as with books.”

Nevertheless, testimony can be a useful tool, especially for pedagogical purposes. Direct observations of the ocean’s floor, the peaks of the Himalayas or the lunar surface are necessarily limited. In such situations, just as with the earliest global explorers, testimony may be accepted unless and until direct observation is possible, or until countervailing evidence is presented.

Revelation is considered by many people as a fourth source of data and information, as well as knowledge and wisdom. It is important to note that revelation is distinct from what Gardiner termed the “Aha!” insight in 1978 (others might reflect on it as a comment made by Archimedes when he jumped into a full bathtub that overflowed and revealed information about overflow principles). Gardiner addressed the question of how looking at a difficult problem in a different way leads to an unexpected, simple solution. This type of insight is similar to that which often occurs when engaged in solving a puzzle. Revelation, on the other hand, takes place without the direct knowledge or action of the percipient. In the present context, it typically refers to communication by a divine or supernatural agency.

Regardless of the source of revelation, it is important to note that a revelation shared with another person is not a revelation for that second person. Rather, it is a form of testimony and subject to the same concerns about its utility as any other testimony. For this reason, revelation is beyond the scope of this essay, which focuses are what data and information can be written on the blank slate and how they can be learned, as opposed to what can be revealed and the benefits of that revelation.

These distinctions in modes of understanding are incorporated widely in our natural languages. For example, Foer (2012, p. 89) reports,

> *Among the Wakashan Indians of the Pacific Northwest, a grammatically correct sentence can't be formed without providing what linguists refer to as "evidentiality," inflecting the verb to indicate whether you are speaking from direct experience, inference, conjecture, or hearsay.*

Evidence – that is, a body of facts or information that indicates validity – is central to scientific inquiry. Evidentiality denotes the nature of the evidence and is a key component of speech and culture...

Reading the Slate

Serpent at the gates of wisdom
Where do you belong?
Wisdom cannot be transmitted
It keeps you hanging on
Do you really serve the Devil
*If it's all God's plan? (*Hitchcock, 1993)

Well… l
Information is
Not knowledge
Knowledge is
Not wisdom
Wisdom is not truth
Truth is not beauty
Beauty is not love
Love is not music
Music is the best... (Zappa, 1979)

In his 1988 presidential address to the International Society for General Systems Research, Russell Ackoff (1989, pp. 3-9) proposed the following model and outline for "knowledge management:"

1. *Data: symbols*
2. *Information: data that are processed to be useful; provides answers to-"who", "what", "where", and "when" questions*
3. *Knowledge: application of data and information; answers "how" questions*
4. *Understanding: appreciation of "why"*
5. *Wisdom: evaluated understanding*

This model was subsequently simplified by Bellinger, Castro and Mills (n.d.), who suggested, "understanding is not a separate level of its own" and presented the revised model shown in Figure 1.

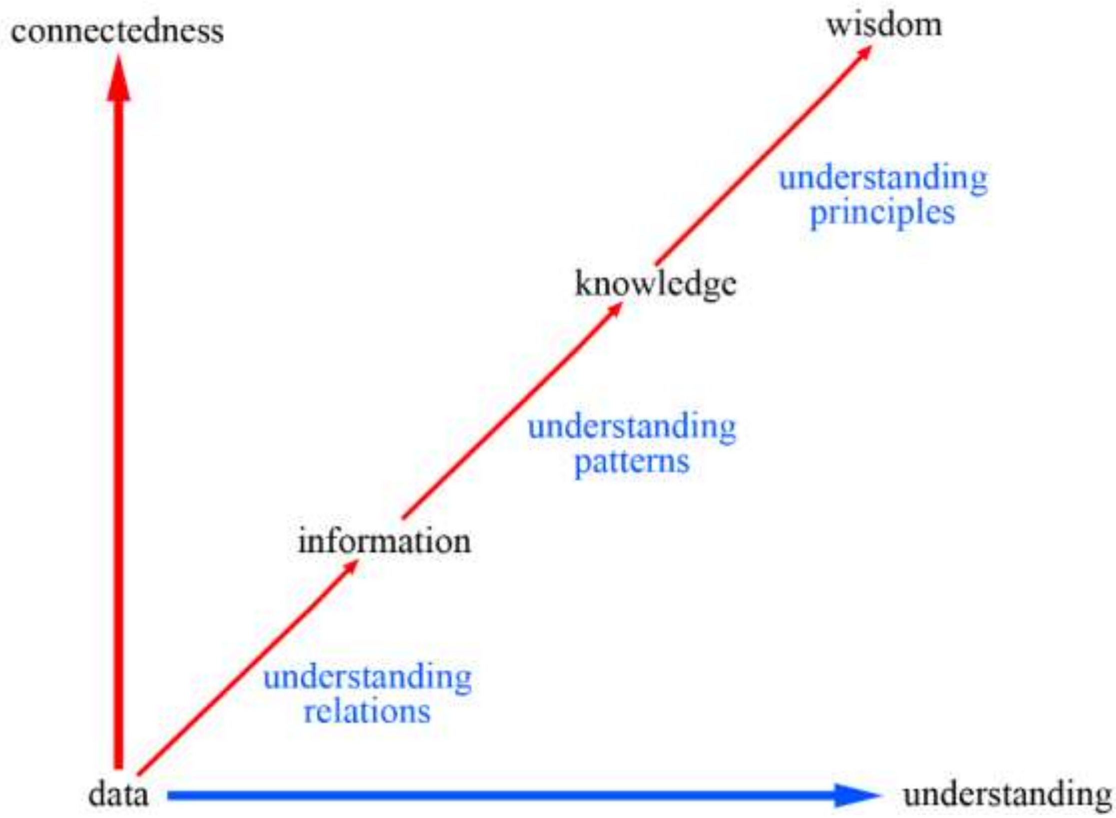

Figure 1. DIKW Model (after Bellinger, Castro and Mills, n.d.)

In this form, the model has come to be known as the Data-Information-Knowledge-Wisdom (DIKW) hierarchy. The model is used widely to describe the ways people assimilate and synthesize observations about the external world.

Sharma (2008) noted that "while the domains of Information Science and Knowledge Management both refer to DIKW, they usually do not cross-reference. Thus there are two separate threads that lead to the origin of the hierarchy." However, as Sharma (2008) also noted, the genesis of the DIKW hierarchy may be traced to a third domain, as presented in the second stanza of T.S. Eliot's 1934 dramatic pageant play, *The Rock.*

> *Where is the Life we have lost in living?*
> *Where is the wisdom we have lost in knowledge?*
> *Where is the knowledge we have lost in information?*

A variation of the DIKW theme was offered by Haeckel and Nolan (1993).

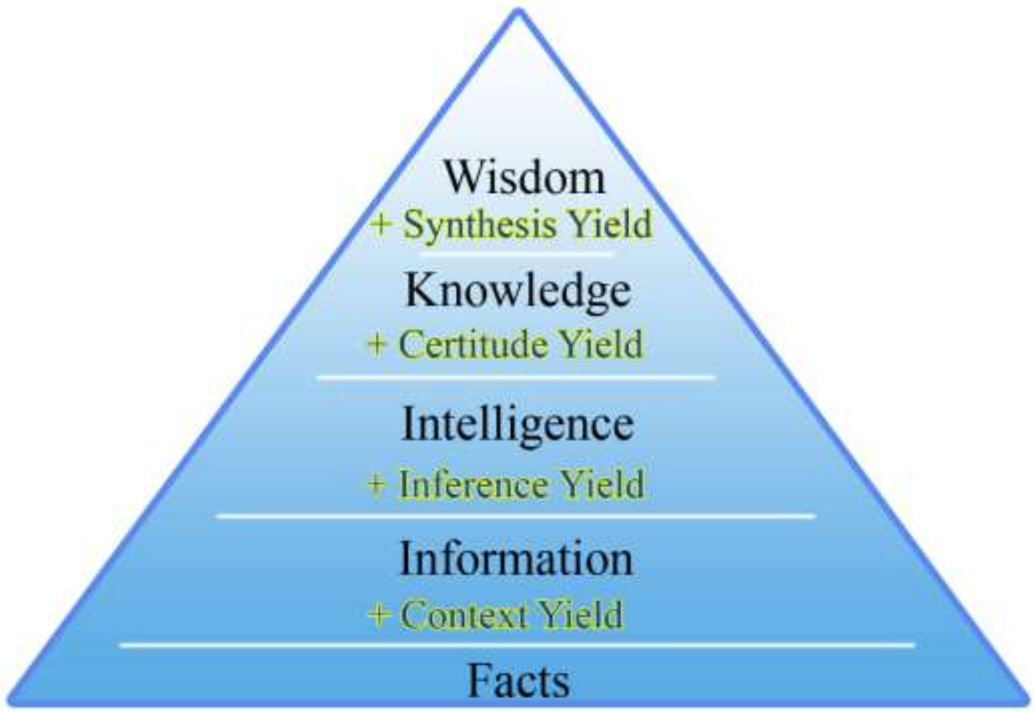

Figure 2. DIKW Model (after Haekel and Nolan, 1993)

> *Reading up from the bottom of the pyramid, facts or data form the basic level of the hierarchy with information being the next level of complexity. Information involves putting data in context, and thereby giving it semantic or quantitative value. By indicating where total sales occurred, for example, one can make information out of data. Intelligence requires machine or human inference. Continuing with the sales example, intelligence involves using reasoning to infer that sales reports are correlated with price differences between two retailers. Knowledge becomes possible when people are convinced of cause and effect after examining intelligence. A salesperson is certain that sales fell in Albany and Boston because prices were raised in those cities. Wisdom is at the top of the information hierarchy, reached only when knowledge is synthesized and evaluated. (*McInerney, 1997)

Another variant of the pyramid was presented by Franz Kurfess (2002) in his California Polytechnic course on Knowledge-Based Systems.

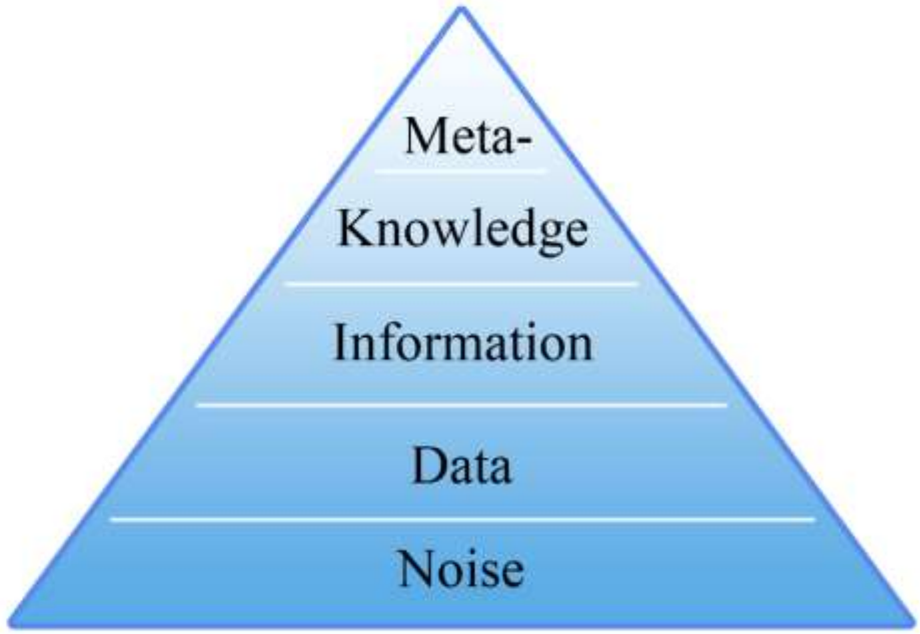

Figure 3. DIKW Model (after Kurfess, 2002)

This model introduces an additional, base layer to the pyramid: noise. The notion of noise in systems, as elaborated by Shannon (1948), is appropriate in the context of this essay, although a minor clarification is necessary. Shannon (1948) viewed the process of communication as one of filtering noise to permit the passage of a signal. For Shannon, this was a mathematical and mechanical exercise. For the purposes of this essay, the role of a mechanical or statistical filter is being played by the selection of a topic for investigation. In other words, the "filter" that is being applied is used to determine which data will be collected to address a particular question.

In addition, this version of the pyramid replaces the notion of wisdom with the notion of "meta" or knowledge about knowledge, which Kurfess found "more descriptive than wisdom" (Kurfess, 2010). Arguably, this closely resembles Hofstadter's (1979) use of the term "meta."

Finally, the Information Technology Infrastructure Library (ITIL) presents this view of the model:

> *DIKW is the ITIL v3 interpretation of Knowledge Management. Represented as a growth path for "understanding," the concept is a good one in that it builds on the traditional view that data (D) becomes more valuable once it is processed into information (I).*
> *DIKW then shows how information becomes the basis for knowledge (K). Knowledge is a collection of experience and ideas and is the element required to understand HOW an activity should be performed.*
> *The final and ultimate piece of the DIKW model is wisdom (W). Wisdom is the pinnacle of understanding and permits a rational answer to the greatest question of all - WHY?"* ("DIKW," *n.d.*)

As implicitly defined here, the transition from data to information to knowledge is, or can be, rather mechanistic. Data plus context equals information. Information plus analysis and confirmation equals knowledge. However, the transition to the next step is less mechanical and far less certain.

Carr (2008) noted that Sergey Brin, the co-founder of Google, had stated in an interview with *Newsweek*, "Certainly if you had all the world's information directly attached to your brain, or an artificial brain that was smarter than your brain, you'd be better off." Carr (2008) continues, sardonically and skeptically, to bemoan the implication of this opinion.

> *Still, their easy assumption that we'd all "be better off" if our brains were supplemented, or even replaced, by an artificial intelligence is unsettling. It suggests a belief that intelligence is the output of a mechanical process, a series of discrete steps that can be isolated, measured, and optimized. In Google's world, the world we enter when we go online, there's little place for the fuzziness of contemplation. Ambiguity is not an opening for insight but a bug to be fixed. The human brain is just an outdated computer that needs a faster processor and a bigger hard drive.*

In other words, the transition from knowledge to wisdom is not easily traversed.

> *Wisdom does not represent large quantities of files, documents or data, but it relies on the distillation of the information, knowledge, and intelligence to produce understanding and insight. Wisdom, in this sense, is 'less,' but it can also be 'more' because it represents a higher value than large quantities of meaningless data. (McInerney, 1997)*

Citing Cleveland (1982), McInerney (1997) continued:

> *Information is a resource and … it should be treasured as we treasure a work of art that is fashioned out of the most basic of elements. Just as a sculptor takes*

> *natural ore, combines it with other materials to make beautiful metal and then shapes it into a sculptural work of art, information has the potential to be a key resource for business decisions and product development. Information, however, must be manipulated by "information artists" to produce anything worthwhile. It is at the highest level, Cleveland maintains, that information is truly transformed into what will ultimately be the kind of wisdom that will make a difference for all types of individuals and organizations. This view of information and its potential elevates the nature of information work to a high art form as well as a science, and, indirectly, it makes the case that greatest care and quality should be applied to information system design.*

The Geospatial Slate

Observations affect the object that is being observed at more than just the quantum mechanical level. Anthropologists have long acknowledged the difficulty of studying a society without directly influencing that society. For example, the Human Relations Area Files, initiated in 1949 to "encourage and facilitate worldwide comparative studies of human behavior, society, and culture" document not only the societies that were studied but also the effects of the studies. In some cases, these effects include adjustments in behavior to gain the approval of the anthropologist. In other cases, certain behaviors that drew reproach were temporarily suppressed.

Occasionally, anthropologists have adopted the participant observation model, in which the anthropologist becomes directly involved in the activities of the people in that society. In other words, instead of just observing the people, the participant observer attempts to gain first-hand experience of how these people live their lives. The results of this activity cannot fail to influence the course of the society being observed.[5]

The act of observation is predicated on a set of choices. Although serendipity will always play a role in field observations, decisions about whom to observe, what to observe, where to observe and when to observe are choices that properly should be made before observations begin. In addition, the justification for making these choices explicit is quite clear. As discussed throughout this essay, the definition of the question pre-defines the answers one obtains.

As a simple example, a geographer may choose to observe a tribe of headhunters and ask how members of the tribe perform the ritual of headhunting. With careful observation, the geographer may be able to determine the answer to this specific question. However, the geographer will not necessarily learn the answer to the question: “How do members of the tribe feel about headhunting in the context of contemporary civilization.” The answer to the first, *asked* question will provide one set of insights into the culture, while the answer to the second, *unasked* question might provide another set of insights.

Thus, the key defining issue in science is not the answer but the question. Therefore, the way we ask questions is critical. As the current national debate about evolutionary biology versus creationism (intelligent design) has highlighted, one of the weaknesses of science is the way questions are framed and theories are presented. It is quite likely that “evolution” may remain a theory forever and yet serve as an accurate description of many aspects of life on this planet.

Butler (2009) characterized this issue as “information relativity” and proposed the following beginnings of a theory of information relativity.

> *1. All information is relative, and it’s always relative: relative to the observer and the observer’s point of view; relative to the culture and its values; relative to the situation; relative to what has come before, and to what will come next.*
> *2. The value of information is always relative because it is directly related to its usefulness, which depends on the user, the context and the situation.*
> *3. Information design must therefore be driven by the context within which it will be experienced. Information design must serve the needs of real human beings doing real things. Information wants to be used.*
> *At its heart, information design is about change. It’s about increasing the amount of useful information in the world. Good information design should result in changes to understanding – increases in knowledge and wisdom – which can be directly measured by observable changes in human behavior.*

As Percival (2005) wrote, “Any "positive support" for theories is both unobtainable and superfluous; all we can and need do is create theories and eliminate error - and even this is hypothetical, though often successful.” Karl Popper’s concept of *falsificationism* identifies this issue clearly. Percival (2005) also wrote, “Falsificationism is the idea that science advances by unjustified, exaggerated guesses followed by unstinting criticism. Only hypotheses capable of clashing with observation reports are allowed to count as scientific.”

Our selection of which questions to ask is constrained by our ability to conceptualize a problem and by our ability to measure the phenomenon. In other words, we cannot ask questions that we cannot imagine and we cannot expect useful answers to questions that cannot be asked properly. The knowledge we gain and the understanding we develop are defined at least as much as by the questions that we ask as they are by the answers (data and information) that we obtain.

Consider the case of a stream flowing from the hills of North Carolina to the Atlantic Ocean. The physical existence of the stream can be confirmed by direct, non-intrusive observation: I can *see* the stream without altering it. My act of seeing the stream does not change the stream – it remains to be seen, in approximately the same position and approximately the same condition – by anyone else who occupies approximately the same vantage point at some proximal same point in time.[6]

Normal geophysical processes taking place over centuries certainly may modify the physical existence of the stream, as may human activity such as strip mining or dredging. The act of confirming the physical existence of the stream, however, is essentially non-intrusive. We can make a remote observation via an earth imaging satellite to confirm the existence of the stream.

Having observed the existence of this stream, there are many questions that could be asked. We might ask the name of the stream or inquire about its ownership. We might ask about the relationship of this stream to other streams in a particular watershed. For the purposes of this discussion, the question we will ask concerns the rate of flow of the water.

To consider the rate of flow, we must make additional decisions to refine the question. The first decision might be the selection of a technology to measure current flow. We might have suitable flow meters available to us from previous studies or we might need to acquire new equipment. We might wish to have the information recorded by the flow meters transmitted remotely (SCADA) or we might wish to visit the meters periodically to confirm proper functioning. After selecting and deploying the technology, we may begin making observations.

The next set of decisions is concerned with the matters of coding, classifying and normalizing the observations. For example, we might use the devices to take observations every hour, for a period of five minutes. We then might aggregate the data for the six hour periods or we might aggregate the flow by week.

From the raw or aggregated data, we may define rates of flow for specific time periods, which we would term "event information." For example, we might calculate the rate of flow for some period of time to determine if there is a change related to an external variable, such as agricultural use of water. We also may attempt to identify patterns in rate of flow, such as seasonal variations. We would term this "actionable information."

Event information and actionable information may be analyzed in several ways. Analysis of patterns through space would, or at least could, result in what we term here "geospatial knowledge." An example of such knowledge might be the production of digital terrain models focused on watersheds. Analysis of patterns through time would, or at least could, result in what we term here "geospatial experience." An example of such experience might be the production of digital flood insurance rate maps.

Finally, the combination of knowledge and experience may, if matched by some measure of intuition and inclination, result in geospatial wisdom. For example, by combining relevant geospatial knowledge and geospatial experience, we might be able to develop an understanding of the consequences of changes in stream flow for human use of the land. This understanding might, in turn, enable us to commit to an appropriate course of action to prevent or at least mitigate the impact.

One way to confirm the utility of this approach to organizing geographical studies is to highlight cases using William Pattison's traditions in geographic thought. In his seminal paper presented at the annual convention of the National Council for Geographic Education, Pattison (1963) delineated "four traditions whose identification provides an alternative to the competing monistic definitions that have been the geographer's lot." These traditions were the *Spatial Tradition*, the *Area Studies Tradition*, the *Man-Land Tradition* and the *Earth Science Tradition*.

Spatial Tradition

Pattison (1963) associates the spatial tradition with "a belief in the importance of spatial analysis, of the act of separating from the happenings of experience such aspects as distance, form, direction and position" and cites Ptolemy as an early exemplar. The spatial tradition is represented by examples from the work of Johann Heinrich Von Thünen (1966), August Lösch (1954) and Walter Christaller (1966). The following examples from this tradition confirm the utility of the DIKW pyramid for studies within the genre.

Consider the case of a city transportation department that is charged with managing the city's street lights and traffic cameras to facilitate traffic flows. The department might logically begin this process by collecting data about road locations and producing a map of that data. The department might also collect historical data about traffic volumes and plot these data on the map of street locations.

Using the map of road locations and historical traffic volumes, the department could extract sufficient information to plan the location of real-time traffic cameras. Thus, information gleaned from examining the first two data sets could be used to define a methodology for the collection of additional relevant data. This type of iterative observation is a fundamental characteristic of scientific inquiry.

With the addition of real-time traffic volumes, a model of traffic flows can be built. This information is essential to building knowledge, in this case, an understanding of traffic demand. This understanding, in turn, allows planners to build "patterns," which allow system operators to make sweeping changes in a matter of seconds to the traffic signaling system to ease traffic congestion and, if necessary, reroute traffic around accident locations or other temporary impediments to travel. Typically, these patterns would be adjusted based on their efficacy.

Over some period of time, a larger pattern may emerge. The iterative process of data collection, information extraction and knowledge development may be repeated through several events, seasons or other time periods to build a thorough understanding of the *in situ* system. In the hands of a skilled practitioner, this understanding can serve as the platform for the development of wisdom. For example, the traffic planner may identify or design new routes to minimize wait times and the impact of heavy vehicles on existing routes or may use this understanding to plan urban pedestrian spaces that co-exist beneficially with traffic corridors (Dunlap, 2009).

A second example of the application of the DIKW framework within the spatial tradition is offered by crime mapping. Several law enforcement agencies have observed certain patterns in criminal behavior that seemed amenable to geospatial analysis. The City of Tampa Police Department (TPD), like many other agencies, sought to eliminate the anecdotal character of such observations and apply formal tools to the study of crime.

As a starting point, the department chose to use the FBI's standard definition of Part I offenses, which include the violent crimes of murder, forcible rape, robbery and aggravated assault and the property crimes of burglary, larceny-theft, motor vehicle theft and arson (Federal Bureau of Investigation, 2009). Although reporting is voluntary, this methodology has been adopted widely in the Unites States.

In this case, data collection is a self-actuating event: a criminal commits crime and thereby defines a data point in time and space. TPD began by classifying all crimes in accordance with the FBI's definitions and assigning geographic coordinates to each event. These data were analyzed in conjunction with other selected data, including dates and times of day of the crimes.

The data were loaded into a geographic information system (GIS) for analysis. The process mirrored an existing analog method of geospatial analysis, in which crimes were mapped using color-coded, round-headed pins placed on a wall map. The end result was a "dot" map of crimes; criminals were known colloquially as "dot-makers."

The advantages of moving to a digital GIS are obvious: occurrences are reported and stored for rapid, multivariate analysis of distributions and concentrations of criminal activity. Combined with empirical information about criminal behavior, this knowledge allowed TPD to engage in daily, and in some cases near real time, redeployment of officers. The net effect of this and related efforts was a 46% reduction in Part I offenses between 2003 and 2008 (Tampa Police Department, 2009).

Building on this knowledge, TPD developed a measure of wisdom about crime correlations. For example, abandoned houses are prime locations for certain criminal activities, including illegal drug use. A correlation of crime with the rolls of abandoned buildings registered with the City's Code Enforcement and Business Tax Division strengthened TPD's ability to engage in more point-specific preemptive action. This knowledge and wisdom was shared, in turn, with the Tampa Fire Rescue (TFR) department, which was often called to the site of fires started by users of "crack" cocaine. Additional correlations with data such as building heights allowed TFR to assess more accurately the equipment requirements, including ladder heights, and water pressure requirements that would be needed in the most likely locations.

Area Studies Tradition

Pattison (1963) cites Strabo as a practitioner of this tradition, which focuses on "the nature of places, their character and their differentiation." An example of the application of the DIKW paradigm confirms once again its utility for geospatial analysis.

Consider the analysis of remotely sensed agricultural production. Data may be collected using a variety of sensors, including multi-spectral scanners. In addition, ground truth data may be collected to provide confirmation points for registration of data of a map, as well as confirmation of ground features to validate subsequent analysis.

These data are examined and spectral reflectance curves and signatures derived through analysis of multiple wavelengths of data. These signatures, in turn, may be examined in conjunction with the ground truth data to confirm crop type, classify the features and identify moisture load, among other attributes.

This information may be examined further to estimate crop maturity and output, which will enable accurate estimates of food production. This knowledge, in turn, will assist economists to forecast the transportation requirements for crop aggregation and redistribution. In a less pleasant scenario, it would support planning for distribution of foodstuffs to areas in which food production is expected to be inadequate.

With practice, it is to be hoped that planners would develop sufficient wisdom from these events to predict future fertilizer use and crop rotation strategies necessary for sustainable yields. In conjunction with relevant studies of soil types and conditions, this could also lead to appropriate decisions designed to mitigate or prevent soil erosion and related problems.

Man-Land Tradition

Pattison (1963) cites the work of Spate (1960) who nominated Hippocrates and his essay *On Airs Waters and Places* as an early representative of the man-land tradition. The collection of essays by Thomas (1956), *Man's Role in Changing the Face of the Earth*, which grew from one of the first major conferences on ecology, is a more recent exemplar.

As a simple example, consider a person charged with participating in the design of a roadway in hilly terrain. Field studies might produce data concerning the types of soil and rock that must be removed to create level road beds, as well as the dimensions of trees to be removed and/or relocated. In addition, surveys would produce elevation data.

These data could be used to generate digital terrain models (DTMs) or triangulated irregular networks (TINs). Combined with weight and volume data for dirt, rock and trees, this could be used to perform volumetric calculations and provide information that could be used for planning.

Using this information, transportation engineers could determine how much waste material must be loaded and moved during road construction. This, in turn, would dictate the reservation and scheduling of trucks and drivers and the arrangements necessary for proper disposal or reuse of the materials removed.

Finally, we would hope to develop sufficient wisdom to consider the question of the impact of debris removal and deposition on the ecosystem. We also expect the planners to take appropriate steps to ensure the stability of the road cut (for example, consideration of the need for remediation to minimize erosion). We might also wish to ensure that these aspects of the overall program did not adversely affect the ecosystem within which these changes were accomplished.

John Snow's classic 1849 report on the 1831-1832 cholera outbreaks in London is another notable example of this tradition. When cholera broke out in London once again in 1854, Snow mapped the location of, and demonstrated an association with, contaminated water supplies. "Snow's classic study offers one of the most convincing arguments of the value of understanding and resolving a social problem through the use of spatial analysis." (Crosier, n.d.)

Earth Science Tradition

Pattison (1963) wrote,

> *Only by granting full stature to the earth science tradition can one make sense out of the oft-repeated adage, "Geography is the mother of sciences." This is the tradition that emerged in ancient Greece, most clearly in the work of Aristotle, as a wide-ranging study of natural processes in and near the surface of the earth. This is the tradition that was rejuvenated by Varenius in the 17th century as "Geographia Generalis." This is the tradition that has been subjected to subdivision as the development of science has approached the present day, yielding mineralogy, paleontology, glaciology, meteorology and other specialized fields of learning.*

As an example of the DIKW model's use within the earth science tradition, consider a (hypothetical) researcher who has been contracted by the Federal Emergency Management Agency to analyze flood hazard in a particular watershed. The first step would be to collect data about stream flow, historical rain fall patterns and extremes, elevation and slope, ground cover, soil type and other related variables.

From these data, the researcher would build DTMs or TINs and produce run-off models that summarized these variables as useful information. This information would be synthesized to produce knowledge such as flow volume calculations and maps of 100-year, 200-year and 500-year flood zones. In the final step, the researcher might be called upon to develop a strategy to mitigate flood impact and a wise approach to land management.

One portion of this process is shown schematically – as a work flow – in Figure 4.

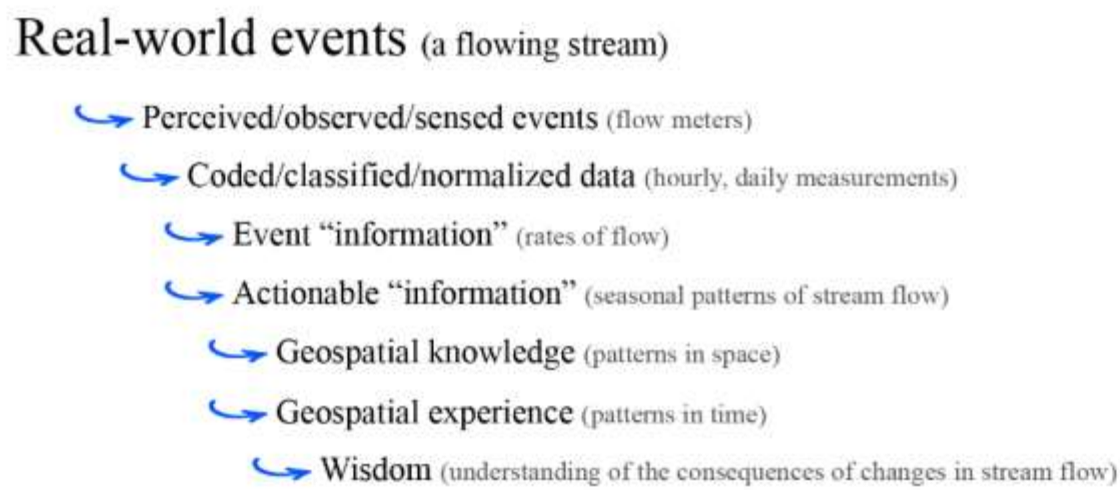

Figure 4. Sample DIKW Workflow

Martin Haigh's studies of slope erosion are examples of this approach. Haigh (and his colleagues) used erosion pins to measure erosion on strip-mine-disturbed lands in several countries. Measured over periods of five years, six years and longer, this research measured "the quantity and distribution of soil loss" and related "sediment pollution problems" (Haigh, 1977).

Conclusion

In this article, we have considered the *tabula rasa*, or blank slate, concept of knowledge. This model of learning focuses on the nature of observation and role of the observer in the learning process. We examined the ways in which data can be collected and processed before being written on the blank slate. We also considered the ways in which the slate, after it is no longer blank, may be read and interpreted, which led us to the notion of the data-information-knowledge-wisdom pyramid.

The relatively easy incorporation of the four traditions of geography within the framework of the DIKW pyramid suggests the utility of a geospatial DIKW pyramid model. The most difficult task in the majority of research programs is framing the question to be considered. This is true because the answer to a question, although perhaps not immediately discoverable, is inevitable. A geospatial DIKW pyramid approach provides a robust framework for identifying appropriate questions and, in due course, writing on the *tabula rasa*. Hopefully, this approach will also allow us to gain some measure of geospatial wisdom about humanity's impact on our home world.

References

"DIKW," *The ITSM Encyclopedia*, http://itsm.certification.info/dikw.html (accessed January 20, 2010).

"Epistemology," *Wikipedia*, http://en.wikipedia.org/wiki/Epistemology (accessed January 17, 2010).

"Geography," *Answers.com*, http://www.answers.com/topic/geography (accessed January 17, 2010)

"George Berkeley," *Wikipedia*, http://en.wikipedia.org/wiki/George_Berkeley (accessed January 13, 2010)

"Hayy ibn Yaqdhan," *Wikipedia*, http://en.wikipedia.org/wiki/Hayy_ibn_Yaqdhan (accessed January 17, 2010)

"John Locke," *Wikipedia*, http://en.wikipedia.org/wiki/John_Locke (accessed December 22, 2009).

"Lysenkoism," *Wikipedia*, http://en.wikipedia.org/wiki/Lysenkoism (accessed January 19, 2010).

"Uncertainty Principle," *Wikipedia*, http://en.wikipedia.org/wiki/Uncertainty_principle (accessed January 10, 2010)

Ackoff, R.L. (1989), "From Data to Wisdom," *Journal of Applied Systems Analysis*, Volume 16, pp. 3-9.

Aquinas, Thomas, *Summa Theologica* (1952), Fathers of the English Dominican Province (trans.), Sullivan, D.J. (ed.), vols. 19–20 in Hutchins, R.M. (ed.), *Great Books of the Western World*, Chicago: Encyclopedia Britannica, Inc.

Argue, D., Morwood, M., Sutikna, T., Jatmiko, Saptomo, W. (2009), "Homo floresiensis: A cladistic analysis, " *Journal of Human Evolution*, 57:5, pp. 623-639 (November).

Aristotle, *On the Soul* (*De Anima*) (1936), Hett, W.S. (trans.), in *Aristotle, Volume 8*, pp. 1–203, London: Loeb Classical Library, William Heinemann.

Baird, F.E. and Kaufmann, W. (2008), *From Plato to Derrida*, Upper Saddle River, NJ: Pearson Prentice Hall (especially pp. 527–529, cited in "John Locke," *Wikipedia*, http://en.wikipedia.org/wiki/John_Locke, accessed December 22, 2009).

Bellinger, G., Castro, D. and Mills, A., "Data, Information, Knowledge, and Wisdom," http://www.systems-thinking.org/dikw/dikw.htm (accessed January 17, 2010).

Berkeley, G. (1734), *A Treatise Concerning the Principles of Human Knowledge*, section 45. [Originally published 1710.]

Brown, P., Sutikna, T., Morwood, M.J., Soejono, R.P., Jatmiko, Saptomo, W., E. & Rokus Awe Due (2004), "A new small-bodied hominin from the Late Pleistocene of Flores, Indonesia," *Nature* 431: 1055-1061 (October 28).

Butler, B. (2009), "The Relativity of Information," http://makinginfouseful.com/tag/information-relativity/, July 6, (accessed December 15, 2009)

Carr, N. (2008), "Is Google Making Us Stupid?" *The Atlantic* (July/August), http://www.theatlantic.com/doc/print/200807/google (accessed December 1, 2009).

Cassidy, D., "Werner Heisenberg and the Uncertainty Principle, "http://www.aip.org/history/heisenberg/ (accessed January 17, 2010)

The Chautauquan (1883), June, Volume 3, Issue 9, page 543 (cited in "If a tree falls in a forest," *Wikipedia*, http://en.wikipedia.org/wiki/If_a_tree_falls_in_a_forest (accessed January 19, 2010).

Chown, M. (2007), "Has observing the universe hastened its end?" *New Scientist* http://www.newscientist.com/channel/fundamentals/mg19626313.800-has-observing-the-universe-hastened-its-end.html, November 22 (accessed January 17, 2010).

Christaller, Walter (1966), Central *Places in Southern Germany*, Englewood Cliffs: Prentice Hall; translation by Baskin, C.W. of *Die zentralen Orte in Süddeutschland* (1933), Jena: Gustav Fischer.

Tampa Police Department (2009), "Focus on Four - Crime Reduction Plan" http://tampafl.gov/dept_police/Files/publications/2009FocusOnFour-Annual-Report.pdf (accessed March 2, 2010).

Cleveland, H. (1982), "Information as Resource," *The Futurist*, (December) pp. 34-39.

Coady, C.A.J. (1992), *'Testimony; A Philosophical Study'*, Clarendon Press, Oxford.

Cohen, I.B. (1985), *Revolution in Science*, Cambridge: Harvard University Press.

Cooley, M. (1987), *Architecture or Bee?* London: The Hogarth Press.

Crosier, S, (n.d.), "John Snow: The London Cholera Epidemic of 1854," Center for Spatially Integrated Social Science, http://www.csiss.org/classics/content/8 (accessed February 8, 2010).

Dunlap, D. (2009), "No Vehicles, but Plenty of People on Broadway," *New York Times* (May 24), http://www.nytimes.com/2009/05/25/nyregion/25bway.html.

Eliot, T.S. (1934), "Choruses" from *The Rock*, Faber & Faber.

Federal Bureau of Investigation (2009), "Crime in the United States," http://www.fbi.gov/ucr/2009prelimsem/index.html (accessed March 2, 2010).

Federal Bureau of Investigation, "Uniform Crime Reporting (UCR," http://www.fbi.gov/ucr/ucrquest.htm (accessed March 2, 2010).

Foer, Joshua (2012), "Utopian for Beginners," *The New Yorker*, December 24, pp 86-97.

Gardner, M. (1978), *Aha! Insight*, New York, W.H. Freeman & Company.

Grigg, D. (1965), "The Logic of Regional Systems," *Annals of the Association of American Geographers*, September, pp. 465-491,

Haeckel, S.H. & Nolan, R.L. (1993), "The Role of Technology in an Information Age: Transforming Symbols into Action," pp. 1-24 in *The Knowledge Economy: The Nature of Information in the 21st Century*, Queenstown, MD: The Aspen Institute.

Haigh, M.J. (1977), "Erosion of Surface-Mine-Disturbed Land at Henryetta, Oklahoma: Some Preliminary Results," *Proceedings of the Oklahoma Academy of Science*, 57, 173-175.

Haigh, M.J. (1979), "Ground Retreat and Slope Evolution on Regraded Surface-Mine Dumps, Waunafon, Gwent," *Earth Surface Processes*, 4:2 (April-June), 183–189.

Haigh, M.J. and Gentcheva-Kostadinova, Sv. (2002), "Ecological Erosion Control on Coal-Spoil Banks: An Evaluation," *Ecological Engineering*, 18:3 (January), 371-377.

Haigh, M.J. and Wallace, W.L. (1982), "Erosion of Strip-Mine Dumps in La Salle County, Illinois: Preliminary Results," *Earth Surface Processes and Landforms*, 7:1 (January/February), 79–84.

Hartshorne, R. (1939), *The Nature of Geography,* Association of American Geographers.

Hartshorne, R. (1959), *Perspective on the Nature of Geography,* Association of American Geographers.

Heisenberg, W. (1927), "Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik," *Zeitschrift für Physik* 43: 172-198. English translation: Wheeler, J.A. and Zurek, H. (1983), *Quantum Theory and Measurement* Princeton Univ. Press, pp. 62–84.

Heisenberg, W. (1930), *Physikalische Prinzipien der Quantentheorie,* Leipzig: Hirzel. English translation: *The Physical Principles of Quantum Theory* (Chicago: University of Chicago Press, 1930).

Heylighen, F. (1993), Epistemology, Introduction, *Principia Cybernetica*, http://pespmc1.vub.ac.be/EPISTEMI.html (accessed January 17, 2010)

Highfield, R. (2007), "Mankind 'Shortening the Universe's Life,'" *The Daily Telegraph*, http://www.nhne.org/news/NewsArticlesArchive/tabid/400/articleType/ArticleView/articleId/3918/language/en-US/Mankind-Shortening-The-Universes-Life.aspx, November 21 (accessed January 19, 2010).

Hitchcock, R. (1993), lyrics from "Serpent at the Gates of Wisdom" from the album *Respect*.

Hitchens, Christopher (2003), "Mommie Dearest," slate.com, October 20, http://www.slate.com/articles/news_and_politics/fighting_words/2003/10/mommie_dearest.html

Hitchens, Christopher (2007), *God Is Not Great: How Religion Poisons Everything*, Twelve Books, New York.

Hofstadter, D. (1979), *Gödel, Escher, Bach: An Eternal Golden Braid*, New York: Basic Books.

Human Relations Area Files, http://www.yale.edu/hraf/ (accessed January 17, 2010).

Ibn Sina (Avicenna), *De Anima* (*Fi'l-Nafs*) (1954), Rahman, F. (trans.), London.

Ibn Tufail (Abubacer), *The Improvement of Human Reason: Exhibited in the Life of Hai Ebn Yokdhan* (*Hayy ibn Yaqzan*) (1708), Ockley, S. (trans.), London: Edmund Powell.

Krygier, J.B. (1995), "Cartography as an Art and a Science?" Cartographic *Journal* 32, 6: 3-10.

Kurfess, F.S. (2002), Microsoft PowerPoint presentation for *CPE/CSC 481: Knowledge-Based Systems*, *Knowledge Representation*, California Polytechnic University, http://users.csc.calpoly.edu/~fkurfess/Courses/CSC-481/W02/Slides/Knowledge-Representation.ppt (accessed 12/15/2009).

Kurfess, F.S. (2010), *personal communication*, March 2, 2010, "Re: DIKW."

Locke, John, *An Essay Concerning Human Understanding*, (1996), K.P. Winkler (ed.), Indianapolis: Hackett Publishing Company, especially pp. 33–36.

Lösch, A. (1954), *The Economics of Location*, New Haven: Yale University Press

Malinowski, B.K. (1922), *Argonauts of the Western Pacific*, London: G. Routledge & Sons, Ltd.

Mankiewicz, D.M. and Carabatsos, S.W. (1966), "Court Martial," *Star Trek: The Original Series*, Season 1, Episode 20, Production number: 6149-15, first aired 2 February 2, 1967.

McInerney, C. R. (1997), "Information Science – An Art and A Science" [monograph on the Internet], New Brunswick, NJ, Rutgers, The State University of New Jersey, http://www.scils.rutgers.edu/~clairemc/infsci.html.

Morwood, M.J.; Soejono, R.P., Roberts, R.G., Sutikna, T., Turney, C.S.M., Westaway, K.E., Rink, W.J., Zhao, J.- X., van den Bergh, G.D., Rokus Awe Due, Hobbs, D.R., Moore, M.W., Bird, M.I. & Fifield, L.K. (2004), "Archaeology and age of a new hominin from Flores in eastern Indonesia," *Nature*, 431, pp. 1087-1091 (October 28).

Nietschmann, B.Q. (1973), *Between Land and Water: The Subsistence Ecology of the Miskito Indians, Eastern Nicaragua*, New York: Seminar Press.

Pattison, W.D. (1963), "The Four Traditions Of Geography," Paper presented at the opening session of the annual convention of the National Council for Geographic Education, Columbus, Ohio, November 29

Penrose, R. (2004), *The Road to Reality: A Complete Guide to the Laws of the Universe*, Random House Group (Knopf), pg. 807.

Percival, R.S. (editor) (2005), *The Karl Popper Web*, http://elm.eeng.dcu.ie/~tkpw/ (accessed January 17, 2010).

Plato, *Cratylus*, from the *Dialogues* (1871) Jowett, B. (trans.), Project Gutenberg Ebook, http://www.gutenberg.org/files/1616/1616-h/1616-h.htm (accessed January 20, 2010).

Ray, J. (1691), *The Wisdom of God Manifested in the Works of the Creation.*

Rizvi, S.H. (2006), "Avicenna/Ibn Sina (CA. 980-1037)," *Internet Encyclopedia of Philosophy*, accessed December 21, 2009).

Rorty, R. (1989), *Contingency, Irony, and Solidarity*, Cambridge: Cambridge University Press.

Scientific American (1884), Supplement 431, April 5, page 218 (cited in "If a tree falls in a forest," *Wikipedia*, http://en.wikipedia.org/wiki/If_a_tree_falls_in_a_forest (accessed January 19, 2010).

Searle, A. (2005), "Secrets of the forest," *The Guardian* (December 20), http://www.guardian.co.uk/artanddesign/2005/dec/20/photography.secondworldwar, (accessed January 31, 2009).

Shannon, C.E. (1948), "A Mathematical Theory of Communication," *Bell System Technical Journal*, Vol. 27 (July and October), pp. 379-423 and 623-656.

Sharma, N. (2008), "The Origin of the Data Information Knowledge Wisdom Hierarchy," http://nsharma.people.si.umich.edu//dikw_origin.htm (accessed January 17, 2010).

Simpson, G.G. (1961), *Principles of Animal Taxonomy*, New York: Columbia University Press.

Snow, J. (1849), “"On the Mode of Communication of Cholera" (pamphlet).

Spate, O.H.K. (1960), “Quantity and Quality in Geography,” *Annals of the Association of American Geographers*, Vol. 50, No. 4 (December).

Tampa Police Department (2009), “Focus on Four - Crime Reduction Plan” http://tampafl.gov/dept_police/Files/publications/2009FocusOnFour-Annual-Report.pdf (accessed March 2, 2010).

Thomas, W.L. (ed.) (1956), *Man's Role in Changing the Face of the Earth*, Chicago: University of Chicago Press.

Von Thünen, J.H. (1966), *The Isolated State*, New York: Pergamon Press, translation by Wartenburg, C.M. of *Der isolirte Staat in Beziehung auf Landwirthschaft und National-Ökonomie, oder Untersuchungen über den Einfluß, den die Getreidepreise, der Reichthum des Bodens und die Abgaben auf den Ackerbau ausüben*, Hamburg 1826.

Weinberg, S. (2005), "Einstein's Mistakes," *Physics Today*, 58: 31, November.

Zappa, F. (1979), "Packard Goose" from the album *Joe's Garage: Act II & III* (Tower Records.

Zeleny, M. (1987), "Management Support Systems: Towards Integrated Knowledge Management," *Human Systems Management* 7:1, pp. 59-70.

Notes

---

[1] Much later, Berkeley's thought experiment was satirized in a two-stanza limerick attributed to Monsignor Ronald Knox.
There was a young man who said "God / Must find it exceedingly odd / To think that the tree / Should continue to be / When there's no one about in the quad."
"Dear Sir: Your astonishment's odd; / I *am* always *about in the quad. / And that's why the tree / Will continue to be / Since observed by, Yours faithfully, God."*

[2] This discussion admittedly ignores current thinking in the field of physics that negative gravity (i.e., dark energy) does not function at these scales of activity. "Because the amount of negative gravity in any given volume should be minuscule, its effects would not be felt in everyday life. But over vast distances involving huge volumes of space, the effect would be powerful enough to push galaxies and clusters of galaxies apart from one another." (http://www.gravitywarpdrive.com/Negative_Gravity.htm) (accessed January 17, 2010)

[3] The counterintuitive nature of this principle has given rise to some humor. For example, it is claimed that Werner Heisenberg was driving along a highway when a police officer pulled him over to the side of the road. The officer walked up to his window and asked, "Sir, do you know how fast you were going?" Heisenberg replied, "No, but I know where I was." As a second example, in Episode 36 (Production Code 2ACV04, "The Luck of the Fryrish") of the television program *Futurama*, a horse race announcer proclaims, "It's a quantum finish! And the winner is … Harry Trotter." The reaction of a losing bettor, Professor Farnsworth was, "No fair, you changed the outcome by measuring it."

[4] Coady (1992) argues that we do not need to have reasons for believing in testimony, only an absence of reasons not to believe it. In a different context, Hitchens (2007, p. 150) argued, along similar lines, "That which can be asserted without evidence can be dismissed without evidence." Hitchens reiterated this position in traditional print in 2007 (Hitchens, 2007, p. 150). Known as Hitchens Razor, this is a restatement of an older, anonymous Latin proverb: *Quod gratis asseritur, gratis negatur (*which may be translated as "What is asserted gratuitously may be denied gratuitously").

[5] For an introduction to the concept of participant observation, see Malinowski, B.K. (1922), *Argonauts of the Western Pacific*, London: G. Routledge & Sons, Ltd. For an example of the approach, see Nietschmann, B.Q. (1973), *Between Land and Water: The Subsistence Ecology of the Miskito Indians, Eastern Nicaragua*, New York: Seminar Press.

[6] We ignore for this discussion the observation attributed to Heracleitus by Plato in his *Cratylus,* "SOCRATES: Heracleitus is supposed to say that all things are in motion and nothing at rest; he compares them to the stream of a river, and says that you cannot go into the same water twice." Plato, *Cratylus*, from the *Dialogues* (1871) Jowett, B. (trans.), Project Gutenberg Ebook, http://www.gutenberg.org/files/1616/1616-h/1616-h.htm (accessed January 20, 2010)

*Dr. Austin is Adjunct Faculty at the Center for Interdisciplinary Geographic Information Technology at Delta State University and President of Austin Communications Education Service, Inc. By appointment from the U.S. Secretary of the Interior, he served as Chair of the National Geospatial Advisory Committee from 2013 through 2015.