Introduction

Linguists, information scientists, learning scientists, and educational technologists define and use information differently. An increasing amount of information affects nearly everyone. Computers are getting better at storing and retrieving information, getting smarter, and becoming more like expert decision makers in many fields. While human experts (e.g., chess masters or world-class tennis players) relate to information differently than novices, experts also know things that machines find difficult to learn. We (as a species) remain in constant pursuit of newer and deeper information. What distinguishes the various forms of human intelligence from machine intelligence? In this article, information is explored from the perspectives of linguistics, information sciences, learning sciences, and educational technologies.

Language Structure, Meaning, and Peak of Uncertainty

A language is a connection between sounds, symbols, and meaning: a connection between something conceptual and something perceptible (Jakobson, 1937). One question to be answered is: does what one has heard end up in the same part of one's brain as what one has seen in sign language? Does the information in our brain reside in one place in our brain, or is it shared throughout the brain holographically? With respect to how useful the information may be, does it make a difference how the information was acquired?

Information can be measured by degrees of uncertainty (Shannon, 1948; Shannon & Weaver, 1971). In the 1940–1950s, Harris (1946) had a breakthrough in the study of syntax, one of the four subfields of linguistics (namely, phonology/phonetics, morphology, syntax, and

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semantics). Phonology is the study of the sound structure of a language; morphology is the study of how words are made: syntax refers to the study of how to make phrases, clauses, and sentences; and semantics is the study of meaning, the most opaque of the four enterprises. Harris believed that meaning could be represented as a function of negative entropy.

Harris (1946) shows how one can arrive at the morphological structure of a word—its prefixes, root(s), and suffixes—without knowing anything about the meaning of the word. For instance, the word ‘independently’ is a combination of two prefixes ‘in’ and ‘de,’ added to ‘pend,’ plus two suffixes ‘ent’ and ‘ly.’ Harris discovered that by investigating how many sounds could follow each of these “morphemes,” it could be established that there were peaks of uncertainty at the boundaries of each morpheme, but much less uncertainty within each one. Similarly, if one had to guess the sequence of letters in a telegram, though one might have to make many guesses to find the beginning of the first word (for all letters of the alphabet can start a sentence), the greater the number of letters of a word one has guessed correctly, the fewer are the possibilities of the remainder of the word. After the sequence ‘sc,’ we can find any vowel or r or l, but after ‘screec,’ we know that only ‘h’ is possible. With each correctly guessed letter in a morpheme, the following possibilities diminish. Harris tries to do away with meaning, because he thinks that meaning is vaporous and too hard to grasp. Therefore, at least mathematically, it becomes more useful to measure the peaks of uncertainty in a message, rather than trying to arrive at the meaning of a word.

One of the active issues in the information sciences is the ubiquitous use of technologies such as computers and applications like Google. We want to have a more useful Google, so that when we ask a question (What NFL team is from Dallas?), we get the one answer we want (The Cowboys) instead of a million answers containing irrelevant information. We want computers to better understand the language we use. Linguists call the attempt to make computers understand language “natural language processing.” Many linguists try to build computers intelligent enough to understand language with no human intervention.

What happens if one receives a message, but doesn’t know what language it is written in? If we encounter something in, for instance, Swahili, we need to find a Swahili speaker, or a computer that can translate Swahili. How does a computer learn Swahili? We can input sets of translated texts in both English and Swahili and feed them into the computer so that the computer learns, similar to chess-learning computers. Since this represents a finite or deterministic problem solution set, the computer makes progress in mapping all of the possible permutations and combinations and learns a representative type of syntax and semantics. After some time and some fine-tuning, the computer may learn all the possible interpretations and then use a probabilistic computation to serve up the most probable meaning intended. Consequently, one of the intersections between linguistics and information sciences is: do we really need grammar? Do we need to teach computers grammar? Do we have to tell the computer that ‘independently’ has five pieces in it? Or can we do everything probabilistically?

**Situational Difference Between Message and Meaning**

Buckland (1991) identified three main uses of the word “information,” namely, information-as-process, information-as-knowledge, and information-as-thing.

- **Information-as-process**: When someone is informed, what they know is changed. In this sense “information” is “the act of informing.”
- **Information-as-knowledge**: “Information” is also used to denote that which is perceived in “information-as-process.”
- **Information-as-thing**: The term “information” is used attributively for objects, such as data and documents, which are regarded as being informative.

Gleick (2012) states that, in a sense, information is about everything: word, writing, early attempts at an analytical engine, telegraph and telephone, and computers. Yet, for the purposes of science, information has to mean something special. Three centuries earlier, the new discipline of physics could not proceed until Sir Isaac Newton appropriated words that were ancient and vague — force, mass, motion, and even time — and gave them new meanings. Newton made these terms into variable quantities, suitable for use in mathematical formulas. In the nineteenth century, the concept of energy began to undergo a similar transformation: natural philosophers adapted a word meaning vigor or intensity. They mathematicalised it, giving energy its fundamental place in the physicists’ view of nature. It was the same with information. A rite of purification became necessary (O’Connor, Kearns, & Anderson, 2008).

Known as the father of information theory, Shannon (1948) defined information using a mathematical formula. Suddenly it became clear there was a distinction and separation between the message and its meaning. The message refers to the coded characters. It is an arrangement of tokens, a priori, and what is observed. The message is merely the carrier of a code. Meaning is more contextual, depending on a recipient’s decoding abilities; meaning is functional, not inherent in a message. For instance, a book about how to program, written in French, would be of little use for a person who does not know French; though, if the requirement were significant, the recipient could arrange for translation. Meaning requires both a coding and decoding process.

We can use a photograph of a lake in the Seattle, Washington area as an example. Although one’s eyes cannot detect the small differences in the photo,
technology enables one to measure the amount of red, blue, and green at different points of the photo. Based on the measurements, a person can generate his or her own meaning, for instance, whether or not the sea state is calm enough to go kayaking that day.

If we use information in Gleich (2012) and Shannon (1948)'s empirical sense, i.e., looking at the structure of a message (the arrangement of tokens), what can we measure and how can we make describable the arrangements in the message? How do we find those elemental pieces? How should we think of the structure we'd like to describe? Specifically, how does a librarian know how to help a user find what he or she is looking for without completely understanding the user or without the user knowing exactly what they themselves want? Shannon's entropy \( H \) is a measure of probabilistic in the system that one is investigating:

\[
H = - \sum p(x) \log p(x)
\]

The consequences of Shannon's model have been astounding in public life: GPS locators, DVDs, and myriad other technological givens of the digital era. In the realm of information retrieval and philosophy, the consequences are no less substantial. We can now measure the information of documents in languages we do not know and even in non-linguistic documents such as videos, making analyses and rapidly indexing beyond human capability and yielding interpretation-free descriptions. The “subject” no longer inheres in the document; deep topographic mapping of the information, the structure, enables new forms of use, new means of coming to meaning.

Bateson (2000) defined information as “a difference which makes a difference” (p. 448). It is the difference we note that makes an appreciable difference in what action we will take now or in the future, given the distinction we have just discovered. If we think of information as a difference, or a dissonance, we start to understand how our prior understanding had been incomplete and what attributes of the whole need to be completed.

**Ethics and Wisdom in Information and Educational Technology**

Many educational technologists think of information in terms of a hierarchy ranging from data to information, knowledge, instruction, competency, understanding, and ultimately to wisdom.

1. **Data** are unstructured and decontextualized, which can take many forms (text, sound, images, graphs, videos, etc.).

2. **Information** consists of structured and interpreted data that can typically be put into the form of one or more claims—that is to say, assertions that can be tested or used in a variety of ways to represent ideas and prompt actions (Austin, 1962).

3. **Knowledge** refers to information claims that are well established and widely accepted.

4. **Instruction** may be knowledge that is associated with and pertinent to a learning goal. Instruction also includes learning activities, sequences that may build on prior instruction and increase in complexity, and feedback to learners to ensure the development of competency and understanding.

5. **Competency** refers to the ability to perform a particular task with repeatable reliability, under various conditions, and with measurable outcomes.

6. **Understanding** refers to what we do in response to various situations and especially with how we explain actions, decisions, and phenomena; understanding typically requires relevant knowledge and competence and the ability to transfer what has been learned in one context to a new context.

7. **Wisdom** is hard to describe directly and also difficult to measure; according to Dreyfus & Dreyfus (1986), wisdom is at the highest level of intuitive understanding; knowing when it is appropriate to do something and when is not appropriate to do it; however, it is not clear how to systematically and effectively support the development of intuitive understanding and wisdom.

According to Quine and Ullian (1978), we build our understanding based on the interconnected beliefs we have. We have a variety of beliefs; many beliefs are not supported by evidence. When new information is encountered and new knowledge developed, relevant beliefs are activated. When a particular belief is challenged, an entire set of beliefs connected with that particular belief are thereby challenged. Our beliefs are the lens through which we view and understand the world; this was put in the following way by Wittgenstein (1921); the world of the happy person is not the same as that of the unhappy person; the world waxes and wanes as a whole. As such, we have an ethical obligation to constantly examine our beliefs and question the information received.

Gould (1991) recounts a case where Walcott, an American paleontologist, discovered a fossil of a sea creature several thousand meters above sea level. Walcott's first question was how the fossil of a sea creature came to be so high above sea level. That discovery did not fit his prior belief that sea creatures generally live at or below sea level. He then spent a great deal of time trying to find living examples of the fossilized animal. None could be found. He realized he had a buried belief that such creatures were still living somewhere, which then had to be abandoned. As it happens, the discovery of that fossil in the Burgess shale led to many others. Old beliefs about the formation of the Rocky Mountains and about sea life were abandoned and new belief structures gradually took their place.

The typical human behavior is to follow an existing
belief and the message of a crowd, and to overlook something that challenges an existing belief structure (Le Bon, 1895). However, if one wants to learn, one might need to consider alternative views and new sources of information. One purpose of education is to develop new knowledge structures, which often involves challenging existing beliefs. If one is not willing to admit that one does not know (i.e., that one is willing to restructure one’s beliefs and knowledge structures), then one is not in a position to learn.

In Philosophical Investigations (Wittgenstein, 1953), published after Wittgenstein died, the notion of a language game was introduced to work through how groups of people come to share understanding and approach the problem of distinguishing that which makes sense from that which does not make sense. We create internal representations and then talk about those representations with others in a form of discourse that is loosely governed by rules understood by the members of that language community. These abilities form the basis for a socio-constructivist epistemology, which is widely accepted by philosophers, psychologists, and instructional designers.

To learn, to find truth, and to develop expertise, McClintock uses the concept of inward study in reference to Plato. Teachers “could not fruitfully instruct those who would not teach themselves, who would only respond passively to the most convenient appearance; the most teachers could do was to convert such inert souls to active study” (McClintock, 1971, p. 12). McClintock suggests that often the “true” information is “in the experiences that each of us has”...consequently, the value of words is not that “they communicate truth, but that...they may help us grasp and comprehend the truths of our experience” (McClintock, 1971, p. 56). Bransford, Pellegrino, and Donovan (1999) suggested that the ability to monitor one’s approach to problem-solving—to be metacognitive—is an important aspect of expert competence, and that “students need to develop the ability to teach themselves” (p. 38). In other words, teaching is not about sending messages or answering questions. Rather, teaching is about getting students to have questions. To have a question is more difficult than asking a question. To have a question, one must (a) admit that one does not know, (b) commit time and effort in search of an answer or explanation, (c) be open to alternative explanations, and (d) be willing to question one’s assumptions and unstated beliefs.

To become an expert on a domain of knowledge or skill, Ericsson, Krampe, and Tesch-Romer (1993) tell us that it takes more than 10 years of deliberate practice. This concept of 10-year or the “10,000-hour rule” was popularized by Gladwell in Outlier (2008). Duckworth and Quinn (2009) advocate that grit—an individual’s passion for a particular long-term goal, coupled with the perseverance in overcoming obstacles or challenges—serves as a driving force in achievement realization.

Supporting the development and the pursuit of understanding requires an environment that facilitates access to relevant resources and activities as well as support for inward study, true discourse, and the progressive development of expertise (Lin, 2008). Progress in the planning, implementation, deployment, management, and evaluation of learning environments and instructional systems requires research and evaluation pertaining to the selection and sequencing of relevant information as well as scaffolding to help learners develop their internal representations, engage in discourse about those representations, and continue with their own investigations and explorations. In the information age, developing understanding, becoming an independent thinker, and developing wisdom are more challenging than ever before.

**Conclusion**

In this article, we have discussed the concept of information from the lens of linguistics, information science, learning sciences, and educational technology. We highlighted the concepts of (1) learning language through meaning or probability; (2) the situational difference between message and meaning; (3) relationships between beliefs and information; (4) the many hours necessary to build mastery, competency, or expertise; and (5) the importance of ethics and wisdom in the world of big data and new technologies.

All four disciplines have a goal to address the relationships between information, technology, and people. This goal is characterized by a commitment to learning and understanding the role of information in human endeavors. In all walks of life, expertise in all forms of information is required for progress in science, business, education, and culture. This expertise must include understanding of the uses and uses of information, their intentions, as well as information technologies and their applications.

In the ever-increasingly fast-paced world, as we collect and examine our data, we seldom have time to do a thorough job before we move on to the next set of measures. We record the information that is good enough. We present the information we believe is representative or serve our purpose. The question comes as to what are we willing to accept as representative information; what probability will represent the truth.

Computers are good at storing and retrieving data and information. Ideally, the large amount of data and information stored and retrieved help us better understand the facts and truth. Yet, how do we know who is filtering the information, and what is the agenda behind filtering the information? Without a critical examination of the data and information before and after they are stored and retrieved, is it possible we are only further away from the facts and truth? We all agree that wisdom is the highest level of human knowing, yet we cannot say exactly what wisdom is or how it is devel-
Concept-Mapping Tools and the Development of Students’ Critical-Thinking Skills

Sheng-Shiang Tseng

Developing students’ critical-thinking skills has recently received attention at all levels of education. This article proposes the use of concept-mapping tools to improve students’ critical-thinking skills. The article introduces a Web-based concept-mapping tool—Popplet—and demonstrates its application for teaching critical-thinking skills in classrooms.

Introduction

Advancements in technology have changed the nature of learning. Students can use the Internet and social media to seek help, share content, and present information in multimodal forms, including texts, photos, and videos. The valid use of technological tools for help-seeking, information-sharing, and knowledge-presentation requires students to possess critical-thinking skills. Critical thinking is defined as the “process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action” (Scriven & Paul, 1996). In other words, critical thinking is a reflective-thinking ability by which students judge and confirm accuracy, significance, and validity of the information they collect (Bean, 2011; Shihab, 2011).

Critical thinking consists of two elements: skills and dispositions (Facione, 2007; Yang & Chou, 2008). Critical-thinking skills are associated with cognitive skills, including those of interpretation, analysis, evaluation, explanation, inference, and self-regulation (Facione,

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