True Computer Literacy and Core Concepts for Non-majors

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Abstract

Teaching only the tools of computing (i.e. word processing, spreadsheets; databases and Internet topics) and calling it computer literacy is unacceptable. For our students to truly be prepared for the future world of computers they need more than just the tools of today, many of which may not even exist tomorrow. They should understand what data and information consist of and how computers work. It is also important that the student be familiar with the general applications of computers: visual communication, audio communication, network communications, information systems, simulation, artificial intelligence & evolutionary computation and education & training. In other words, students in today's world must be fluent in information systems and computer science. One way this fluency can be acquired is by introducing concepts in an order that allows concepts introduced earlier to be used as a basis for later conceptual ideas. This paper shows one possible path through a comprehensive set of concepts used in information systems and computer science.

Keywords: Core concepts, non-majors, literacy, fluency

1. Introduction

It is evident from the many names given to the fields related to information and computers that there are equally many points of view about what is and is not important. It has also become clear over these past years that the practitioners of these various fields expend great energy in keeping up in their own areas. These two factors certainly contribute to that fact that courses to teach non-majors about what computers are and how they are used have become orphans. These courses are often considered by the research/high level faculty to be unattractive teaching assignments. As a result, many colleges and universities hire part time people to teach them. After all, why would liberal arts majors need to know about von Neumann computers or neural networks? In fact, colleges and universities seem to be following a trend that endorses training and vocational education. This is quite evident in the course offerings to non-majors: wordprocessing, spreadsheet, data bases, multimedia and Internet related topics. Many of these courses tend to be teaching how to use programs and specific products. What has happened to the pursuit of knowledge for understanding and concepts? Are we really addressing what can truly be called *computer literacy*.

The National Research Council was asked to examine this problem, and in turn instructed the Computer Science and Telecommunications Board to study it. They issued their report *Being Fluent with Information Technology* in 2000 (National Research Council 2000). However, there are some deficiencies in the report. In particular, the level of competence in the various aspects in being fluent is not addressed as pointed out by Peter Denning (Denning 2000). This paper will concentrate on the concepts and the level of competence that is compatible with Denning's observations.

2. Comparison with other Fields

It is not too hard to find courses in physics, economics, chemistry, political science and many other areas that are concerned with the non-major. A rather extreme example from years ago occurred in the physics department at California Institute of Technology. Nobel Laureate Richard Feynman taught freshman physics to the general population of Cal-Tech students. It is interesting to note that this course was published as the Feynman Lectures, and over thirty-six years later they are still in print. Or from another

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viewpoint, introductory chemistry courses don't focus on teaching glass blowing techniques or learning the tools of chemistry. Instead efforts are made to introduce the non-major to the beauty of nature's chemistry, and how it effects our lives. All of the older academic areas seem to give an importance to their non-majors course that is far beyond the attention given this area by the academic fields related to computing.

There are two observations that stand out from the many comparisons to other academic areas:

1. Many of these academic specialties take a great deal of pride in their introductory non-majors courses. After all, these introductory courses represent that field to the majority of people exposed to it.
2. Introductory courses can be deadly, and can poison a students feeling to the field. Just look at the reputations of physics and economics. Students don't readily sign up for introductory courses in these fields out of fear of failing.

Is it possible that we can learn from these observations? Can we take the best ideas from the various fields and create an approach that fosters pride leading to academic success, where the students gain the greatest benefits. The first thing that must be done is to identify what the field of computer and information systems encompasses. It is irrelevant that it be called computer science, information systems, informatics or any other name. In the rest of this paper the name information systems will be used, but any of the others are equally applicable.

3. Core Concepts

It is not easy to get agreement amongst information systems people as to what constitutes a core concept. Other fields of science have a similar difficulty, but not to the extent we do in information systems. For example, in physics, every introductory course must treat the subject of the forces of nature, such as gravity. Similarly in information systems no one can argue that the concept of what constitutes information is irrelevant. But, would this justify approaching the concept of information from an *information theory* point of view? I don't think so! In fact, most courses just assume a student understands what is meant by the term information. What has to be agreed upon, is how deep the understanding must go to be of value to the non-major.

The ordering of the concepts being taught is also important and somewhat flexible. However, there are several constraints that make a fairly natural ordering. For example, it is necessary for the student to be familiar with the binary representation of different types of information before introducing concepts on how to store it. A more specific use of these basic concepts is in understanding why MP3 audio files do not have the quality of full fidelity CD files.

The first task is to establish a base line of concepts and the depth of understanding of these concepts. Posing a series of questions, whose answers are the core concepts, will initially be used. These questions will be addressed to the first of two categories called theory. The second category of general application will follow. However, we shouldn't let the names to be more than enablers for discussion. It should also be pointed out that the proposed list of core areas and example concepts are meant as examples or a starting point for discussion and far short of a complete proposal. Starting with the theory category several major core areas seem likely.

4. Core Concepts in Theory Category

Certainly one of the first core areas involves understanding what is meant by the term *information*. It is important here to realize that individual specializations of information systems may use this term with different meanings. This paper will use the definition from the **Encyclopedia of Computer Science,** which states that "information is data which is used in decision making," where the decision making can be done either by human or computer. It should be noted that the distinction between data and information is not important here. In fact, one person's information can be another person's data. Now to the first core area concept.

Representation of information raises two very important questions that are related:

What is the information that computers process?

How is the information represented in the computer?

Almost all information that computers deal with consist of one of *five kinds of information*:

- numbers
- characters
- visual images
- audio
- instructions

After identifying these five kinds of information, the next step is to represent them in a form that is compatible with computers. Many introductory books and courses at this point will say that "the binary form of representation is used because it can use switches that are either on or off." This is a very misleading answer, because for one thing, on/off is binary. In fact, it is not even an answer to the question as to why computers work in binary. Aside from some historical pressure attributable to boolean algebra, the fact is that *computers work in binary because it is both reliable and economical*. Certainly more reliable and economical than the old electro-mechanical base ten calculating machines such as those manufactured by

Friden, Monroe, or Marchant in the 1950s. In the next millennium with quantum computers on the horizon, no one knows what base used for the representation of information will be the most reliable and economical.

As an example of the importance of understanding the concept of representation of information, one only needs to look at the MP3 revolution. Record company executives really didn't *get it* when bringing CDs onto the market, they treated them just as they would analog records and tapes. Then the MP3 digital representation standard caused the revolution that stood the industry on its head.

The next question pointing to core areas follows logically:

Where is the binary information kept?

In answering this question *primary and secondary memory* of the computer are addressed along with reasons and examples for both. Although, the purpose of primary memory will be best explained when the discussion of the von Neumann computer model is addressed via the question:

How do computers work with binary information?

At this point the very important concepts of *algorithms* and *programs* must be introduced. The importance of algorithms is obvious when some computer professionals prefer to define information systems as the study of algorithms. Dealing with this concept can be accomplished by examining a simple computer, such as a robot, which has many human actions. The process would be to create algorithms for the robot. Once the concept of an algorithm and program are developed, the von Neumann model of the computer can be addressed. The concepts involved with the von Neumann computer can be nicely done by visually observing how it works though some type of simulation. This would mean looking at the primary memory, watching the fetch/execute cycle happening visually, and noting the limitation of the single program counter. The concepts involved in answering the previous question:

How do computers work with binary information?

are many and difficult to explain unless a visual simulation of the process is involved. Some of the concepts which make sense to include are:

- algorithm
- program
- fetch/execute cycle and clock speed
- program counter
- primary memory

These concepts are examined in the context of the classic model that identifies CPU, Memory, Control and ALU. This model illustrates the basic Input, Process and Output operations.

With a foundation in this core area, the student will be prepared to understand the concept of a supercomputer.

The next most obvious question is:

How can this complicated system be controlled?

This is an extremely important core area, because the student's main contact with a computer is via the operating system. Some of the appropriate core concepts are listed below:

- booting up computer
- command line Vs. GUI interface
- file management
- I/O
- multitasking
- real time process control
- distributed processing

Controlling the computer via the operating system leads easily to the next question:

How is an algorithm communicated to the computer?

This brings up many core concepts involving computer languages. It is also a good place to discuss the use of high-level communication of algorithms via applications such as spread sheet programs. Just a few of the core concepts in this area are:

- procedural/ object oriented/ functional languages
- syntax Vs. semantics
- program life cycle
- program constructs (e.g. if/then, loops)
- simple data structures

Again, it sometimes seems that certain details, such as looping in a language, is not appropriate for computer literacy. An example that argues for it is the case of the toy manufacturer who created a toy called "Big Trak." The toy tank was used for awhile in schools, but it could only loop exactly twice. If that toy had a loop structure capability, it might still be used today to teach hands-on programming. The kids really liked "Big Trak," but it was substantially limited for purposes of teaching.

The last core area in the theory category is the most visible and influential of this decade. It involves the Internet and the ubiquitous computer. The former president of IBM, John F. Akers, predicted a future where "everything is connected to everything." This area is introduced by the question:

How do computers communicate with each other?

This is a core area that everyone agrees should be one of the foundations in becoming *computer literate*. Just a few of the many concepts that are included on everyone's list are:

- direct connection Vs. packet switching
- analog Vs digital communication
- speed of communication
- network server

In summary, the core areas for the theory category should answer the questions repeated below:

What is the information that computers process?

How is the information represented in the computer?

Where is the binary information kept?

How do computers work with binary information?

How can this complicated system be controlled?

How is an algorithm communicated to the computer?

How do computers communicate?

The answers to these questions certainly are not sufficient to make a person computer literate. In fact, they don't indicate how all of this power is applied to our world problems.

5. Core Concepts in the Applications Category

The word *applications* has many meanings. Some computer scientists identify it with the tools of computing, namely wordprocessing, spreadsheets, data bases, and network communications. A more general definition of the word can also mean a particular use of the computer that cuts across all boundries in all fields of intellectual endeavor in a way that is beyond mere tools. A list of such general applications might include the following:

- network communications
- databases & information systems(research & business)
- visual communication
- audio communication
- simulation
- artificial intelligence
- education & training
- real time & process control

Some of these general applications make use of those that are more fundamental. For example, education & training has instances where all of those above it in the list are used. However, education & training is so important that it is easy to argue for inclusion as a fundamental application of the computer.

It could also be argued that ethics should be included in some important role. However, it would seem that ethics is not an application of the computer, but it is a behavior that should underlie the use of these general applications. This should not diminish the importance of ethical considerations. It can easily become one of the more important aspects of computer literacy by the fact that ethical behavior or its absence is part of using each application on the list. To indicate the importance of the role of ethics in computer literacy, an example of some ethical consideration will be mentioned in the following discussion of each of the general applications.

Network Communications—There are many concepts in this core area. A few of these concepts that would be on most computer scientists list are given below:

- The Internet and its services (e.g., email, WWW)
- network security (e.g., firewalls, virus detection)
- network protocols (e.g., TCP/IP, http, ftp)
- Search engines (e.g.,encyclopedic, index, intelligent)
- file formats
- browser programs
- browser plug-ins for WWW

An important ethical issue in network communications, especially the WWW, is the gathering of user data by major e-commerce companies. For example, in the summer of 1999, Amazon.com started publishing the book buying habits of certain corporations. This was done by publishing the quantity of certain popular titles purchased by corporate employees. The uproar created by the WWW community quickly modified this invasion of privacy.

Data Bases & Information Systems—Collection of information has been going on at least as far back as the Egyptians. However, with the advent of computers and networks, the process has taken on enormous importance. It is said that "possession of information is power." Just a few of the many concepts in this core area are:

- collecting, retrieving and analyzing data & information
- distributed data base
- relational data base
- DBMS
- data base language

Ethical considerations have long been associated with databases, especially in the privacy area. An example of a difficult ethical question involves the movement by police agencies to collect DNA information of individuals for a national data base. Since a large number of the individuals would not have been convicted of any crime, the question of privacy should certainly be asked.

Visual Communication—Of all of the human senses, the most important is vision. In fact, one of the more recent fields of information systems, visualization of information, is the result of this importance. Some of the concepts in this core area are:

- digitizing images
- reflective and additive color (i.e., RGB Vs CMYK)
- false coloring
- image enhancement
- Internet broadcast video
- 3d images
- animation

One of the clearly unethical behaviors in recent years involves the print media. The case involved cover pictures of O.J. Simpson on both Time and Newsweek magazines during the famous murder trial. One of the magazines intentionally used graphic techniques to darken the image of O.J. Simpson to make him look more sinister. This is certainly not at the same level of deception as when fashion photographers remove blemishes from images of model's faces.

Audio Communication—Although our primary sense is vision, the second most important human sense is hearing. Its importance is indicated by the importance of human language development. Again, a small number of concepts for this core area are:

- digitizing audio
- human language phonemes
- voice synthesis & recognition
- Internet broadcast audio
- audio file formats (e.g., MP3)
- MIDI

One of the most controversial ethical issues in this area is the piracy of music over the Internet. With MP3 it only takes minutes to download perfect digital copies of songs from CDs and other sources.

Simulation—This is one of the least recognized general applications of the computer. It underlies many of the major decisions involving the US economy. Government officials use the results of simulations to help guide the economy by running them using different scenarios to see what happens. Unfortunately, not all models are perfect, which leaves the decisions in question. A short list of some concepts related to the core area of simulation are:

- models
- continuous Vs. discrete
- predictable Vs. stochastic
- feedback loops
- virtual reality

One of the most insidious ethical issues in simulation is the intentional biasing of models to get results that support a certain position. All models are biased, mostly due to ignorance, but some are intentionally biased.

Artificial Intelligence—The area of information systems commonly given the name of artificial intelligence is a mix of many attempts to mimic human intelligence, which is supposedly real intelligence. It has a distinct division into to subcategories: human programmed systems and evolutionary grown systems. The names are the main indication as to which camp they belong. A few of the important concepts are:

- knowledge representation, acquisition, and retrieval
- reasoning
- heuristic programming
- game playing
- pattern recognition
- expert systems
- neural networks
- genetic algorithms
- genetic programming
- evolutionary computation

Ethical issues abound in this sometimes esoteric field. One of the first was the suggestion that Joseph Weizenbaum's Eliza program be used for psychiatric therapy. A more delicate and difficult issue is at what point is control of some device turned over to a computer. This is now an issue with pilot control of some complex aircraft.

Education & Training—This core area makes use of many other more fundamental applications. But, as already indicated, it is lifeblood that will push our culture into the future. Without the transfer of knowledge from generation to generation, "reinventing the wheel" would occupy the majority of human intelligence. Some concepts involved are:

- cognitive learning
- psychomotor skills
- social interaction
- distance learning
- drill & practice Vs. tutorial Vs. problem solving

The broader ethical issues involve access to technology for all in our society. It would be unfortunate to create a two class educational community with all of its ramifications.

Real Time Process Control—This is one of the most invisible of core area applications. The fact that all of our automobiles have computer controlled engines and most of the home appliances contain control computers should indicate the importance of this core area. In fact the majority of CPUs in the world are controlling devices from cameras to pacemakers. A few of the important core concepts are:

- synchronizing computers with the outside world
- synchronization of processes
- stable and unstable systems
- positive and negative feedback

These core concepts in the general application of the computer are certainly not complete, but they do give the idea what is meant by a concept.

6. Summary

It is incumbent upon educators in the field of information systems to be concerned with the non-majors level of instruction. Avoiding this responsibility can and will result in unorganized confusion where even departments of "Health and Human Services" believe that they have a right to teach basic ideas in computing. This should sound familiar to those who years ago witnessed the move of some mathematics departments to give up their statistics courses to other departments. Sometimes the results were good, at other times the experiment failed. It is time for information systems and computer science departments to take a good look at what's happening at the freshman non-major level.

It should be pointed out that the list of core areas discussed here is only partially complete. More comprehensive treatments of have been recently published (Hillis 1999: Lauckner 2001).

7. References

National Research Council, Report of the Computer Science and Telecommunications Board, *Being Fluent with Information Technology,* 2000. http://www4.nationalacademies.org/news.nsf/isbn

Denning , Peter J., A Commentary On Fluency in Information Technology, *Inventio*, 2, 1 (Feb.2000) http://www.doiiit.gmu.edu/Archives/spring00/pdenning_1.html

Hillis, Danny, *The Pattern on the Stone*. Perseus Books, 1999.

Lauckner, Kurt and Lintner, Mildred. *The Computer Continuum*, Upper Saddle River: Prentice Hall, 2001.