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ABSTRACT

While California has frameworks defining what concepts are necessary for understanding science, math, history-social science, and other disciplines, there has been no such framework for technology. The framework presented in this paper proposes a strategy for thriving in a future that will be strongly influenced by technology. That strategy is based on a contextual approach to understanding technology. The framework presents a hierarchy of understanding from the concrete mechanics of operation up to key concepts that endure across generations of technology and to essential questions that guide the learning process. It is complemented by a lesson plans document (available online at KnowledgeContext.org) that implements the framework approach in detail. This paper puts the California Science Framework (1990) into context and discusses drivers of technological development. It presents a hierarchy of the essential questions, key concepts, and mechanics for understanding technology and outlines benefits of this conceptual and contextual approach to understanding technology. Essential questions that are at the root of the Technology Framework are identified, and are then mapped to key concepts of technology. (AEF)

TECHNOLOGY FRAMEWORK

By KnowledgeContext.org

For Grades Five Through Twelve

California, 1999

Audience

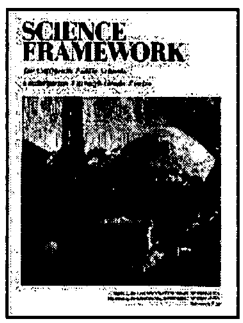
This document is intended for educators interested in teaching the concepts of technology, whether in a technology class or as a connecting theme within a science, mathematics, history-social science, or English-language arts class. This curriculum is a complement to the how-to-use curriculum typically presented in computer or technology classes.

Source

This document is produced by KnowledgeContext, an educational non-profit corporation recognized as a 501(c)(3) by the IRS. Reproduction of this copyrighted document is permitted with credit of source. For further information visit KnowledgeContext.org or contact Miguel F. Aznar at aznar@KnowledgeContext.org.

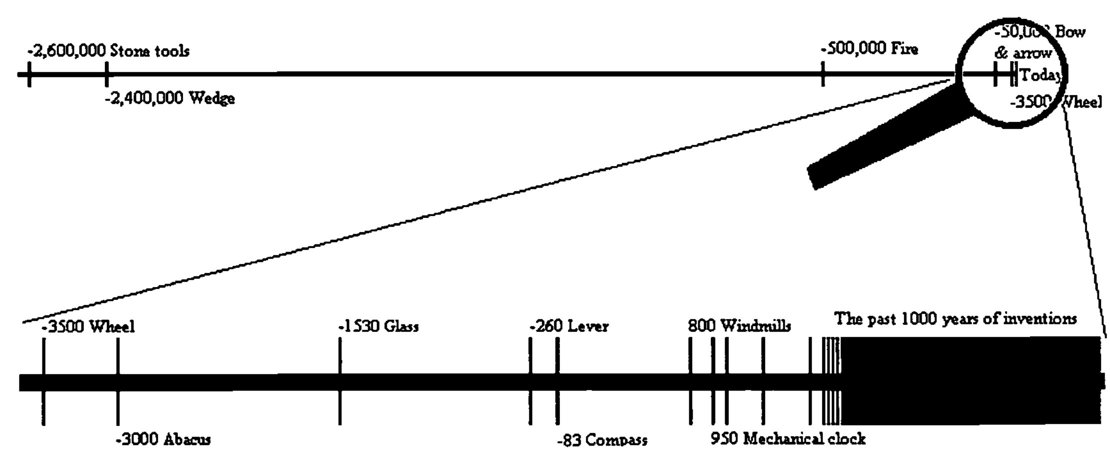
Introduction

As technology extends into every aspect of our lives, it becomes clearly important for our schools to convey an understanding of it to young people. While California has frameworks defining what concepts are necessary for understanding science, math, history-social science, etc., there has been no framework for technology.



Instead, young people are taught the mechanics of how to use it, often with technology that is already obsolete. But knowledge of even current-generation technology is subject to quick obsolescence by the accelerating rate of change. The solution, as proposed in this Technology Framework, is not to replace, but complement. The complement to useful, vocational mechanics is a strategy for contextual understanding. Rafting down a river, you need a paddle to get where you're going and a map to know where that is. This Technology Framework is the map for navigating rapid technological change.

Technology is something that extends our abilities. Since stone tools, it has taken the form of lever, wheel, plow, printing press, computer, network, genetic engineering, and more. Technology has also taken less tangible form as methods of use, methods of production, and software. As such, it has transformed our lives. Perhaps by its very nature, technology changes at an ever accelerating pace. The transformative effect that it has on our lives combined with the quickening generations of successor technologies makes understanding it crucial. Context is key to understanding.



Putting technology in context by teaching concepts benefits students, teachers, business, and society. Students gain a panoramic understanding of technology that connects to their other studies and endures past current technology. Teachers bring context from their broad experience to a subject so new that it often seems the province of students. Business can look forward to potential employees prepared for rapid technological change. Society receives citizens practiced in applying critical thinking to the complex social issues that technology influences.

> The more we study the major problems of our time, the more we come to realize that they cannot be understood in isolation. They are systemic problems, which means that they are interconnected and interdependent.[1]

The framework proposes a strategy for thriving in a future that will be strongly influenced by technology. That strategy is based on a contextual approach to understanding technology. The framework presents a hierarchy of understanding from the concrete mechanics of operation up to key concepts that endure across generations of technology and to essential questions that guide the learning process. The framework is complemented by a lesson plans document that implements the framework approach in detail. This can be used as the conceptual part of a technology class or woven into science or social studies classes.

Schools must consider carefully what curriculum they include in a limited schedule. The dramatic effect that technology has on our lives will only increase as its rate of change accelerates. Learning a strategy for understanding technology—even that which has not yet been invented is becoming an important life skill. This framework fits alongside the other frameworks already part of our educational approach.

[1] Fritjof Capra, The Web of Life. New York: Anchor Books, 1996, p. 3.

Context

The California Science Framework (1990) addresses the nature of science, the major themes of science, and connections between science, technology, and society. To explain its focus on connections, it quotes James Burke:

> This interdependence is typical of almost every aspect of life in the modern world. We live surrounded by objects and systems that we take for granted, but which profoundly affect the way we behave, think, work, play, and in general, conduct our lives and those of our children.[2]

The Science Framework puts science into context because that is key to understanding. Much as it stresses connections between disciplines of science and between science, technology, and society, this technology framework stresses connections.

> One cannot really understand [technology] without an understanding of the roles, incentives, skills, and behaviors that define its use. Technologies are intended to enable us to be stronger, see farther, and think better. We cannot ignore the social and human context in which that occurs...all tools/technologies are a mixture of physical artifact and human behavior patterns.[3]

The very fact that we live surrounded by these objects and systems makes it hard to put them in perspective. This issue is captured in the old saying, "Can't see the forest for the trees" and in a more modern rendition by Marshall McLuhan: "I don't know who discovered water, but it was not a fish." By the time we decide that computers are "the key," the power of networks threatens to eclipse individual computers. Soon thereafter, we recognize networks in their currently popular manifestations of Internet or web as the key. Will it be a biotechnology that next turns our view upside-down? The current incarnation of technology will always tempt our focus with both hype and real value. How do you make sense of it? Context is the key.

Technology branches into countless, unexpected, and not always desired, forms. Predicting or simply understanding these new forms relies on a contextual understanding of technology. Even the great inventors of technology would have had trouble predicting the social impact and relationships of technology.

> Imagine that we brought back Henry Ford to show him today's automobiles. He would not be so surprised by changes in design: cars still have four wheels, steering, front-mounted internal combustion engines, transmissions, and the like. But he would be greatly surprised by the changes in human practices that have grown up around the automobile—for example, hot rods, strip malls, drive-in fast food...rush hours, traffic reports on the radio, and much more.
>
> Alexander Graham Bell would be little surprised by the design of instruments and switching systems—handsets, carbon microphones, dialing mechanisms, crossbar switches, telephone exchanges, and operator services. But he would be amazed by the changes in human customs that have grown up around the phone—telephone credit cards, the Home Shopping Network, universal phone numbers...electronic fund transfers, telemarketing, fax, and telephone pornography...
>
> Edison would doubtless be little surprised by current light bulbs and generators, but he would be astonished by international power grids, night baseball, radio and television, lava lamps, electronics, computers, and much more. For that matter, can you imagine trying to explain frequent flyer miles to Orville Wright? The surprises lie in the way people use new technologies and the new industries that spring from them, in what people see as opportunities and what they see as obsolete.[4]

Understanding a particular generation of a particular technology may have been adequate when human generations passed faster than technological generations. Now, a dozen technological generations pass during a single 25-year human generation. Computer technology is evolving even faster, with silicon chips doubling in both speed and density every 18 months. This rapid and accelerating technological change is forcing each of us to deal with more and more of these "surprises for the great inventors." There are tangible and simple reasons this pace will continue and actually accelerate.

Drivers of Change

Technology is often used to build new technology. This goes back at least to stone and metal tools that allowed primitive man to fashion better tools. Look at a modern silicon chip fabrication plant to see the latest step in a journey to create millions of electronic switches in the space of a thumbnail. You don't do that with stone tools, but you needed stone tools to start the process.

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[2] James Burke, Connections. Boston: Little, Brown & Co., 1980

[3] Tornatzky, L.G. and Fleischer, M. (1990). The Processes of Technological Innovation. Lexington, Massachusetts: Lexington Books, p. 16.

[4] Denning, P.J. (1997). *Beyond Calculation: The Next Fifty Years of Computing.* New York: Copernicus

A bigger impact of technology creating new technology is in the transmission and manipulation of information. Language itself is a manner of technology that conveys the methods of production and use of technology. These methods of production and use are themselves technology. Even if you are reluctant to label them as such, their role does not change. The printing press was a technology that allowed the dissemination of information...including information about technology. Visit Silicon Valley and you will see that the key to making the current generation microprocessor—and most of its ancestors—is in the transmission and manipulation of information. Microprocessor-based computers are in use to translate, aggregate, test, and implement the designs from hundreds or thousands of engineers into the next generation microprocessor. A million hours to create information that will be manifested in a chip the size of a thumbnail.

An inventor of the integrated circuit, Gordon Moore, noted, empirically, that every two years integrated circuits double both in their speed and number of transistors. From a commercial standpoint, we have seen new microprocessors (e.g. 386, 486, Pentium, Pentium II, etc.) and the computers they drive double in power every few years with steady or decreasing prices. The physical limits of integrated circuits may not end this trend, as integrated circuits, apparently, did not start it:

> Remarkably, this "Exponential Law of Computing" has held true for at least a century, from the mechanical card-based electrical computing technology used in the1890 U.S. census, to the relay-based computers that cracked the Nazi Enigma code, to the vacuum-based-based computers of the 1950s, to the transistor-based machines of the 1960s, and to all of the generations of integrated circuits of the past four decades. Computers are about one hundred million times more powerful for the same unit cost than they were a half century ago. If the automobile industry had made as much progress in the past fifty years, a car today would cost a hundredth of a cent and go faster than the speed of light.[5]

Another driver of change is Metcalfe's law. The founder of 3Com and the inventor of Ethernet (used for most local area networks), noted that the value of a network is proportional to the square of the number of nodes in the network. In familiar terms, one telephone in the world is worthless, two is handy, and 200 million is indispensable. The more people you can call, the more you want a phone of your own. This has driven the exponential growth of the Internet. Would Amazon create "the world's biggest bookstore" if the only Internet customers were a few hundred scientists with, perhaps, "focused" interests?

The acceleration in technological change is documented and, if anything, increasing. Version "4.7.1" of anything today will soon be obsolete. Learning the mechanics of how to use a particular technology, while no less important, will become of briefer and briefer value as the rate of technological change continues to accelerate. What knowledge will endure?

Hierarchy of Understanding

Understanding technology can be seen as a hierarchy of essential questions, key concepts, and mechanics. This hierarchy of understanding ranges from the conceptual down to the concrete.

Essential questions serve an important pedagogical purpose: they open the mind to learning and they bring focus. Asking a question draws out the student's personal beliefs and answers to the question. These are associated with an evaluation of the question. Is it important? Is it interesting? The question sets a framework for the important concepts that comprise the subject area content. As questions often have more than one answer, this framework leaves open the discovery of new and even better concepts. The rapid change of technology makes necessary a flexible framework that readily accepts new ways of explaining technology.

Essential questions are answered, in part, by the key concepts, but they allow for students to seek their own answers and for new, better concepts to be discovered. Essential questions are of a general, framing nature, providing a "mountain-top view" of the myriad, evolving technologies below. Essential questions are less content than framework for developing an understanding. A few examples are:

- What is technology?
- Why do we use it?
- Why does it change?

Key concepts are answers to the essential questions. These are not specific to any technology or even generation of technology. Key concepts are the patterns discovered by those who study an area and reflect on it. As such, these "truths" endure beyond knowledge of the mechanics of technology. Some may be as true for the wheel and the lever as the microprocessor and the network. They form the outline for technology content standards and include:

- Technology extends our abilities
- Technology is used to communicate, cure, explore, innovate, shelter, entertain, trade, battle, transport,...any activity that people undertake

[5] Ray Kurzweil, The Age of Spiritual Machines. Viking Penguin, New York, p. 25

- Technology is used to create new technology, causing acceleration in development of new technology

At the lowest—though not unimportant—level is the mechanics of using technology. This practical usage of web browsers, word processors, presentation tools, and computer operating systems is already being taught in many, if not most, schools. It is useful to know how to:

- Search the Internet
- Make a social studies presentation with PowerPoint
- Report on a science project with HyperStudio
- Use graphing software to explore math

The entire hierarchy of essential questions, concepts, and mechanics is important to the understanding and use of technology. Including Essential Questions and Key Concepts with the mechanics that are already being taught in many schools brings benefits to all parties. This Technology Framework does not address mechanics or any form of "proficiency" standards.

Where it Fits

The concepts of technology connect to science, math, and history. The power of the topic lies in its cross-disciplinary nature.

- Scientific concepts explain how it works and, often, how it came to be invented. Technology let scientists view the microscopic and the distant.
- Math describes trends, quantifies impact, and underlies software. Technology let mathematicians see the fractal order of chaos.
- History shows how individuals have influenced it and been influenced by it. Technology changed history with the printing press, steam engine, and computer.

Technology, as taught conceptually, can fit into nearly any core content area to show connections and context. It actually needs these core content areas because they form the context this approach illustrates for technology.

Technology, as taught conceptually, can also fit into conventional technology classes to complement their focus on how to operate technology. This is theory and practice.

Benefits

This conceptual and contextual approach to understanding technology results in benefits to students, teachers, business, and society.

- Students receive both a strategy to thrive in a technological future, but also technological connections to their other studies.
- Teachers see how to apply their experience and breadth of education in teaching technology.
- Business gets potential employees flexible in adapting to rapid technological change.
- Society grows with citizens practiced in evaluating new technology in critical terms of costs and benefits.

Thriving in a future that will be transformed by accelerating technological change requires a strategy for understanding new technologies. The essential questions and key concepts of the Technology Framework, as implemented in the associated lesson plans, gives students practice in understanding technology, both familiar and new. This teaches the strategy.

Connecting technology to students' other studies enriches the context of those studies. It may also hook interest among students enthralled by video games or other entertainment technology and connect that interest to a formal area of study. Where did these technologies come from? How will they change? Who created them? How? Pursuing these questions leads to history, science, and social studies. Technology is a web of connections.

Teachers are often less comfortable with technology than students are. A common comment is "How can I teach these young people anything about technology when they know so much about it and spend so much time playing with it?" Even students practiced in the use of technology often lack the historical, scientific, and social perspective that many teachers have. Connecting those perspectives with technology creates a valuable context for understanding technology. Teachers are well positioned to teach the essential questions and key concepts of technology, even if they invite students to teach some of the mechanics of using technology. Viewing the understanding of technology in a hierarchy reveals the crucial role that teachers can play. It draws on teacher strengths of experience and breadth of education. Teaching something as "new" as technology is based on teaching something as familiar as historical, scientific, and social contexts.

Businesses look to future employees for positions that do not yet exist, as current careers are rapidly replaced by never-before-heard-of careers. Technology was behind the evaporation of many careers in the industrial age, when, for instance, automated machinery replaced weavers in England (leading to the Luddite Movement). Calculators, cars, and airplanes brought more and faster change. Currently, computers and networking are changing the workplace so quickly that many of the types of jobs we will have in just 10 years time do not even exist today. Business needs flexible and adaptive employees that can work with new technology in a contextual manner.

> The companies that drive innovation will not be those that focus narrowly on technical innovation but those that deal with the larger context in

which the technologies are deployed...Much of the most exciting new research and development in computing will not be in traditional area of hardware and software but will be aimed at enhancing our ability to understand, analyze, and create interaction spaces. The work will be rooted in disciplines that focus on people and communication, such as psychology, communications, graphic design, and linguistics, as well as in the disciplines that support computing and communications technologies.[6]

Society relies on an informed citizenry to express opinion on such social-technological issues as privacy of information, technological monopolies, intellectual property, cloning, copyright of movies and music, organization and sources of energy, and much more. Critical thinking about costs and benefits requires practice putting issues in historical perspective, understanding how and why change occurs, knowing how we can play an influential role, and separating the ethical perspectives. Some of the most important and complicated societal issues will pivot on understanding the technological aspects in context. Extending the education of technology beyond mechanics to include essential questions and key concepts benefits students, teachers, business, and society. The widespread implementation of the approach in this Technology Framework will likely reveal additional benefits

Essential Questions

There is no one, correct set of essential questions for understanding technology. The set this Technology Framework has developed is a root question that leads to three supporting questions, each of which leads to three more.

Essential questions open the mind to learning and bring focus to study. The root question is "How do we understand technology?" Answering that so we can understand any new technology we encounter in the future is basic to a strategy for thriving in a technological future. Understanding technology comes from understanding what it is, why we use it, and why it changes.

Answering "What is technology?" requires that we go beyond the casual assumption that it is only computers and networks. These are some of the most recent and pervasive forms, but they ignore biotechnology, which may eventually eclipse them, methods of use and production, and historical forms back to the wheel and control of fire. Considering these gives the farthest view and our age of rapid technological is no time to be myopic. The context of what technology is comes from the three subordinate essential questions:

- Where does it come from?
- How does it work?
- What connections does it make?

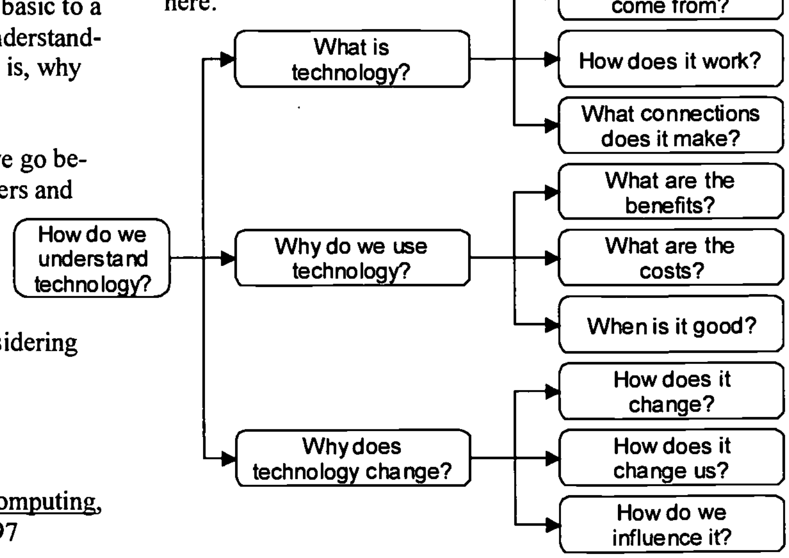
Why we use technology gives us a tool for evaluating it. The reasons we use current technology were around long ago. Communication, shelter, and transportation are three of the oldest motivations, but they continue to drive some of the most modern advances. Evaluation leads to the three subordinate essential questions:

- What are the benefits?
- What are the costs?
- When is it good?

Why technology changes addresses the root motivations and limitations of invention and innovation. Brilliant insights must find social, financial, and manufacturing support to create a viable technology. If no one wanted it, no one was willing to pay to develop it, or no one could make it, little historical record shows that it ever existed. Delving deeper takes us to the three subordinate essential questions:

- How does it change?
- How does it change us?
- How do we influence it?

These explanations of the essential questions are based on the key concepts developed in this Technology Framework, but the essential questions are flexible enough to accommodate new and improve concepts. As new minds consider the questions and new technological developments change the patterns, new key concepts can augment or supplant those identified here.



[6] Beyond Calculation: The Next Fifty Years of Computing, "The Design of Interaction" Terry Winograd. 1997 Springer-Verlag New York, p. 156

Key Concepts

There are many concepts of technology that are increasingly important to understand as technology permeates our lives. No list can be complete, though many lists can be impractically long for teaching purposes. Any list should draw on a variety of sources and remain flexible to revision and improvement. This list was developed with the counsel of a variety of people whose jobs entail preparing their high-tech firms for emerging technology. It is a starting point.

One way to organize key concepts is to map them to essential questions. This is done below, with essential questions, familiar from the previous section, numbered and associated key concepts bulleted below each.

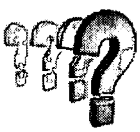
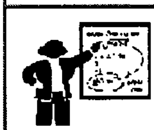
1. How do we understand technology?
   - We understand it by asking powerful questions of people, references, or our own investigations.
   - We understand it in general by understanding a few technologies in particular (induction).
   - We can understand the behavior of a technology by interacting with it.
2. What is technology?
   - It is something that extends our abilities, making something faster, more efficient, or safer.
   - It is hardware, software, and methods, both of use and production.
3. Why do we use technology?
   - We use it to satisfy some need.
   - We use it to communicate, cure, explore, innovate, shelter, entertain, trade, battle, transport...any activity that people undertake
4. Why does technology change?
   - It changes because there are needs that are not met by current technology. It is born of necessity.
   - Technology changes when an idea comes together with support (financial or social) and supporting technology
   - It comes from a combination of insight, persistence, chance, and understanding of patterns like science and math.
5. Where does technology come from?
   - It has a rich history of inventors and influencers that weaves through the major events of civilization.
   - The people who developed new technology came from many backgrounds and circumstances, sharing personality traits with us all.
6. How does technology work?
   - It works according to scientific and mathematical laws.
   - It is almost always built up from other technologies, which are often built up from other, component technologies, like the layers of an onion.
7. What connections does it make?
   - It connects in surprising combinations, relying on other technology, social issues, financial sources, artistic expression, and individual persuasiveness.
8. What are the benefits of technology?
   - It benefits our health, education, safety, range of choice, and—very broadly—our lives.
9. What are the costs of technology?
   - It always has side effects, sometimes on people other than those directly benefiting from it.
   - Costs of it can be measured in terms of the possible unintended consequences and the probability that each will happen.
10. When is technology good?
    - Determining when it is good depends on a person's perspective, values, ethics, and willingness to compromise.
11. How does technology change?
    - It is created with other technology, so it often allows the creation of a new technology.
    - When it allows the creation of a new technology, the rate of technological change accelerates (Moore's Law).
12. How does technology change us?
    - It changes our expectations, attitudes, beliefs, awareness, goals, habits, hopes, and fears by changing what we are capable of and changing what we have information about.
    - It changes our environment, forcing us to adapt, which may cause anxiety.
13. How do we influence technology?
    - People influence it by inventing, developing, supporting, presenting, communicating, marketing, teaching, advocating, and voting.

Lesson Plans

Key concepts are important to understanding technology and essential questions are effective for organizing the many key concepts, but that does not reach all the way to the classroom. That last step to the actual teaching requires that these key concepts and essential questions be incorporated into lesson plans. Lesson plans should be based on learning cycles, with integrated activities and student assessment. Each lesson plan covers one class period and is structured as shown in the table below. The lesson plans are in a separate document and also available on the Internet at KnowledgeContext.org

Conclusion

The transformative effect that technology has on our lives makes understanding the concepts and context of technology important. The rapid and accelerating rate of technological change makes it urgent. This approach complements the how-to-use-computers curriculum already in our schools. It benefits students, teachers, business, and society. Essential questions and key concepts offer a strategy for thriving in a technological future. The vision of this Technology Framework has been developed into detailed lesson plans available for teachers of grades 5 to 12 through workshops, both live and on-line.

 **Focus Question**	The daily Focus Question (usually one of First Context's Essential Questions) keeps the teachers and students focused each day on a single issue so all keep a sense of where they are in their exploration of the concept of technology.
 **Hook**	The Hook engages students and connects the daily issue to the students' knowledge and experience. The hook is suggested in the form of a brief story which foreshadows the lesson. The suggested story can be replaced by the teacher to reflect current events.
 **Key Concepts**	The Key Concepts provide some answers to the daily Focus Question and can lead teachers and students to other considerations and other answers.
 **Objective**	The Objective is stated in terms of student outcomes. It ties together the focus question, lesson, activities, and it guides reflection.
 **Lesson**	The Lesson is training in a key strategy needed to do the day's activity.
 **Activity**	The class Activity gives students guided practice in the strategy taught in the lesson, or the activity gives students a way to inductively learn the day's lesson. It is doing something that helps students answer the Focus Question.
 **Sharing**	Group or whole class Sharing reviews the ideas formed during the class, shares products produced, and pinpoints strategies used that were successful during the class. The sharing demonstrates that the teacher's objective for the day was met.
 **Processing**	Processing/Reflection in a personal journal internalizes the ideas generated in the class and gets the useful strategies into long term memory. Given time to reflect on useful strategies, students learn to think smarter so they can take in more knowledge. Allowing time for students to put acquired knowledge into context gives them an opportunity to construct their own meaning from the knowledge.
Background	Background and current event articles related to the lesson.
Content Standards	Connections to California State Content Standards.

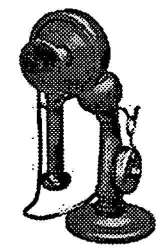
The Challenge

Because of technology's… Understanding technology is…

Transforming nature → Important

Accelerating change → Urgent

Transformation

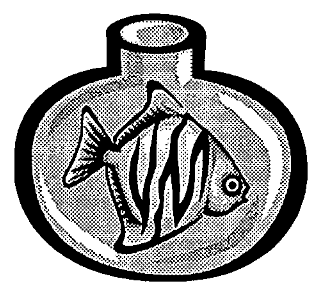


- Telephones and unpaid operators
- Priceline and the reverse auction
- KnowledgeContext and reverse scheduling

Drivers of Change

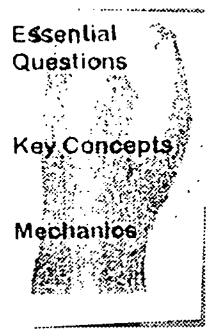
- Tools build tools
- Tools transmit and manipulate information
- Moore's Law
- Kurzweil's Extension
- Rice & chess on exponential growth
- Metcalfe's Law

Context is Key to Understanding



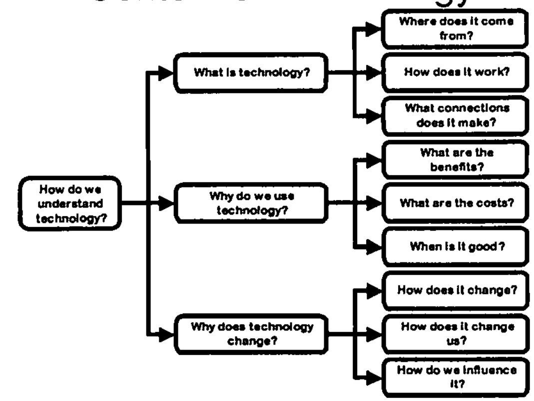
- "I don't know who discovered water, but it was not a fish"—Marshall McLuhan
- AAAS Project 2061
- California State Science Framework
- Technology Framework???

Mechanics vs. Concepts



- What many schools already do
- Complementing, not competing
- Rafting with a paddle and a map

Context of Technology



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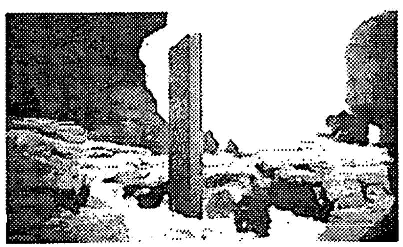

- If Arthur C. Clarke (2001) were our spokesperson
  - 2,000,000 years ago, obelisk says "Use it"
  - Technology transforms our lives
  - Technological change accelerates
  - Now, obelisk would say "Understand it"
- Visit KnowledgeContext.org

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12

13

Welcome

To

Training for Time Travelers

Miguel F. Aznar
KnowledgeContext.org
Aznar@KnowledgeContext.org

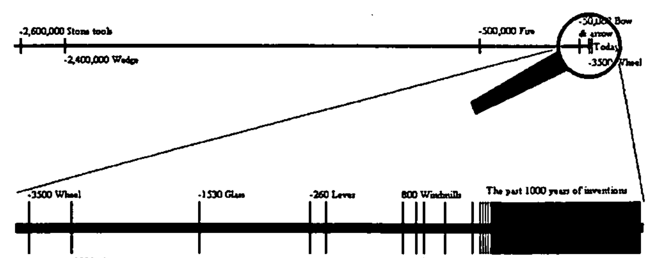
Objective

- Strategy to thrive in a technological future
  1. **Who am I?**
  2. **What is technology?**
  3. **The challenge**
  4. **Drivers of change**
  5. **Transformation**
  6. **Context is key to understanding**
  7. **Mechanics vs. Concepts**
  8. **Context of technology**
  9. **Close**
- Technology framework for you to take

Who am I?

- Technology kid
- UC electrical engineering & computer science
- Silicon Valley engineer
- Management consultant (Ernst & Young, AT&T)
- Volunteer teacher
- KnowledgeContext founder
  - Gave me license to ask IBM, Oracle, Netscape/AOL, Andersen Consulting: "What would you teach your kids about technology?"

What is Technology?



1. More than computers, networks, & "things"
2. Accelerating change
3. Transforming how we live

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