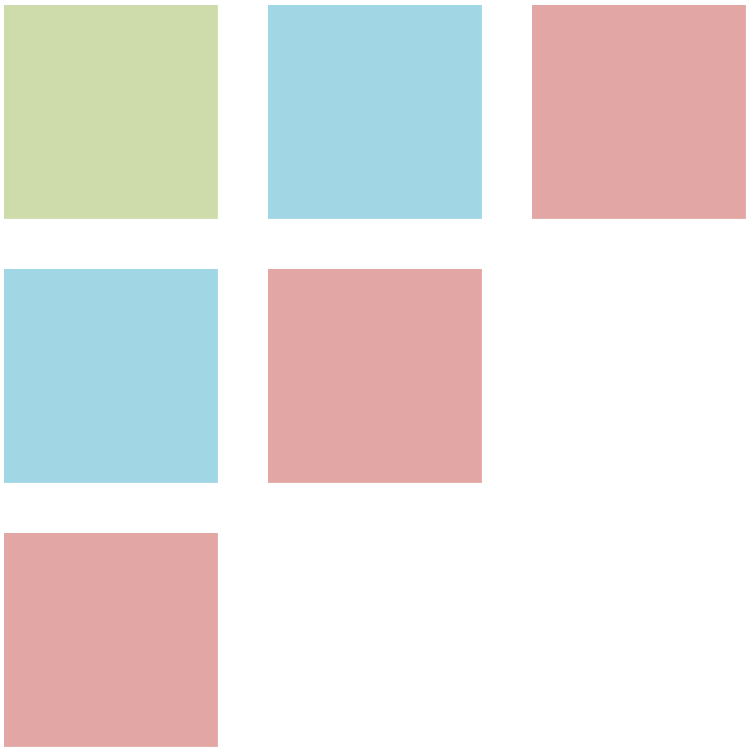

Technical Report:

Standards for Everyone: A Modular Curriculum

NIST Project: DLP12-1015-N00 Award: 60NA

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Project Rationale

The lack of interest in standard education has always perplexed me. Although my introduction to the subject of standards and standards setting was somewhat fortuitous (a request from the US Congress to do an OTA study),[1] once I became acquainted with the subject, I was totally fascinated. I pondered why others weren't as well.

Hearing about the lack of university courses and course materials relating to standards and standards setting, I hoped to bring some of my thoughts and enthusiasm to bear on the problem. It seemed to me that there were a number of aspects to it. For one, many students are unaware of standards, that is to say, they hardly know what they are, and why they matter. Likewise, because standards are somewhat tangential to existing university disciplines, faculty members are generally uninterested and/or unable to dedicate time and effort to incorporate a standards component into their courses. In turn, university administrators, given their limited resources, see no need to prioritize standards as a special area of academic concern.

My experience as the former director and associate professor in the Communication Culture and Technology Program (CCT) gave me some insights about how one might overcome such reluctance. Standards issues have a number of linkages to many CCT courses: they only need to be pointed out. Consider, for example, teaching the following courses without some references to standards, and standard setting.

- Standards: The Global Stakes
- The Network Economy
- Robotics and Society
- Infrastructure Studies
- Expressive Computation
- Privacy and Security
- Intellectual Property
- Network & International Development
- Cyber-learning: Theory and Practice
- Networks and the Creative Process

[1] OTA (1992), *Global Standards: Building Blocks for the Future*, Washington DC: US Government Printing Office.

- ♦ Cultural Hybridity: Mixing Media,
- ♦ ICT Law and Policy
- ♦ Sustainability: Foundations, Technology & Design
- ♦ Product Development in the Digital Age

In applying for this NIST grant, I believed that, if educational standards components could benefit these CCT courses, then they might provide value to other university courses as well. The obstacle to generating such course materials appeared to be one of creating a critical mass of users, as well as developing a critical supply of content. Fortunately, in a digital environment, such obstacles might be more easily overcome. For example, in an on-line environment, demand can be agglomerated not only across university departments but also across universities. Likewise, the supply problem can be addressed by presenting course materials in short modules, so that the size of the effort would be greatly reduced, and faculty members could mix and match the modules to tailor course materials to meet their own specific needs.

This was the rationale behind our NIST application, "Standards for Everyone: A Modular Curriculum" (See appendix a). Our specific aim was to develop prototypes of standards modules that could generate a broader interest in standards while serving as on-line materials for a variety of courses. As described below, in the process of implementing the project, we found it necessary to adapt our ideas and make some changes in the face of unanticipated obstacles.

Implementation of the Project

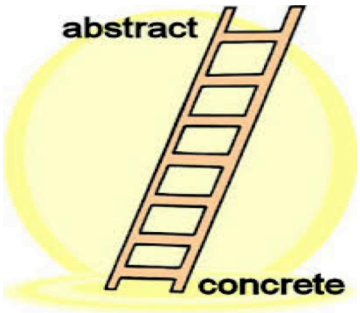
Developing the Modular Scripts

A first step in carrying out our project was to decide which modules we should develop first. To get some feedback, we interviewed a number of faculty members to find out what kinds of materials might be most useful to them. Their reaction was telling. With few exceptions, standards and standardization issues were basically new to them, so as it turned out it was we, rather than they, who had to make the connections. Based on this experience, we determined that the first modules to be developed should be those that defined standards, identified their importance, and laid out the institutional framework for standard setting.

Not surprisingly, the first module we developed was entitled: ***Why Study Standards?*** (See appendix a) Its aim was to illustrate the ubiquity of standards and identify the stakes involved in their development. Conceiving of standards broadly, as the building blocks of society, this module provides a number of illustrations showing how we ignore standards at our peril.

The second module, ***The Standards Universe*** (see appendix a), provides a framework for studying standards issues; it defines standards and scopes out the standards universe, as well as lays out a rationale for differentiating standards for the purpose of analysis. Based on our idea that standards are ubiquitous, and essential to the proper functioning of most everything, we chose a very abstract definition. Our hope was that with a general, abstract definition, we--together with others interested in specific standards or standards issues--might subsequently fill in additional modules, working their way up the "ladder of abstraction."[2]

Defining Standards Working Up the Ladder of Abstraction



According to our definition, standards are interfaces that govern all interactions, be they individuals, machines, words, or elements of the natural world. These interfaces might govern the mode of interactions; define the conditions under which interactions can take place; and/or signify the appropriateness of an interaction. This abstract definition allowed us to view standards not only from an interdisciplinary perspective, but also from a comparative perspective, comparing and contrasting standards processes across a variety of settings.

To differentiate standards according to their specific purposes, and according to how they are established, the module identifies three different kinds of standards: control standards, product standards, and platform standards, as well as three different types of standard setting mechanisms: a *de facto* process, a regulatory process, and a voluntary

[2] James Roseneau (1999) *Thinking Theory Thoroughly: Coherent Approaches to Understanding an Incoherent World*, Westview Press/

consensus process. When matched together in a three by three matrix they constitute what we characterize as "The Standards Universe" (see below.)

The Standards Universe

	Control Standards	Product Standards	Platform Standards
Bottom up/ de facto	Traffic conventions	Popular fads; beanie babies	Language
Top-down/ prescribed	Hours of TV for children	Weights & Measures	Air Traffic control
Voluntary/ negotiated	AMA standards for med practies	Building Supplies	W3C standards

The module *Standards: A Comparative Perspective* (see appendix a) contextualizes standards and standard setting processes within their socio-cultural environments. It compares and contrasts the diverse approaches to standard setting both at the national and international levels. This module not only characterizes diverse standards organizations, and the means by which they arrive at standards, it also identifies the challenges of reconciling differing approaches in an increasingly networks, global environment.

Turning to specific classes of standards, we drew upon examples that not only were diverse, but also not typically addressed by standards experts nor associated with subject of standards. Our aim was to generate a greater fascination with standards, and a desire to learn more about them.

Our module *Standards: The Building Blocks of Life* (see appendix a) is well suited for this purpose. This module is intended not only to be of general interest, but also to spark inquires into standards in such disciplines as biology, physics, and chemistry. In it, we examine the role that standards play in the make-up and functioning of life. Thus, we look at how the molecules in cells carry out their functions via a rule-based (standardized) order,

functioning in effect as "molecular machines.[3]" As well, the module describes how creatures such as slime molds and ants use standardized signals to respond to their environments in predetermined and predictable ways. We show, moreover, how interactions among diverse species exhibit a hidden order based on emergent, rule-based, self-reinforcing behavior.

Many standards inquiries, which focus on the realm of business, are concerned with micro level issues, such as how standards address a specific economic problem, or at how they are used strategically to gain a competitive advantage. In contrast, to illustrate the importance of standards to the economy as a whole, our module, ***Standards: How the West Was Won*** (see appendix a), traces the movement to the US west, and documents how standards, often *ad hoc* in nature and negotiated *en route,* became *the infrastructure*, or platform, upon which, and according to which, travellers journeyed; battles were lost and won; trade was established; and a frontier culture was born. The module illustrates how, as standards paved the way west, the new activities that were thereby made possible generated an even greater need for standards.

Our module ***Standards: The Coin of the Realm*** (see appendix a) highlights the role that social actors play in developing standards as well as the role that standards play in integrating the social order. This module is designed to expand our thinking beyond the techno-economic perspective of standards. In particular, it counters the generally accepted neoclassical economic view that coins first evolved spontaneously in the market as a media of exchange. Building on the recent work of archeologists and historians, it details how political authorities established the first widely used coins to serve non- economic purposes, such as blood and bride money. Only later, when local polities had guaranteed that specific types of coins were redeemable at a standardized value did coinage become a significant means of exchange and an impetus to expanded trade.

Obstacles Along the Way

Our original intent was to develop the standards scripts into digital modules that could be accessed and used by professors interested in incorporating some aspect of standards into their own curriculum. Our biggest impediment to carrying out this part of our project stemmed from a lack of resources, and--given the timing of the project--the inability to get

[3] Goodsell, David S. (2010) *The Machinery of Life, 2nd edition, New York, NY:* Springer Science +Business Media

students involved. We had counted on our students to carry out most of the visualizations of the text: however, by the time we were able to start, most students had other work obligations. Compounding that problem was the fact that my faculty colleague, who was responsible for managing the visual component was beset with numerous health issues, which made it impossible for him to carry out his part of the project. We were left then with text-based scripts.

Shifting Gears

When it became clear to me that the visual aspects of the project were not going to be effectively carried out, I made a choice to spend my time on the project developing a syllabus for a CCT standards course, and testing it out in a new class, *Global Standards: What's At Stake?*. I incorporated the standards scripts that I had written into the course materials, and solicited feed back on them. The course was generally successful, although I am continually thinking of ways to improve it. Most pleasing to me was the decision by one of my students to write her thesis about standards and the poultry industry. It is a ground breaking piece of work.

I drew a number of lessons from my experience. The first related to my theoretical background. Because of my public policy background at the Office of Technology Assessment, I have typically looked at issues from a macro-level perspective (eg. the public good aspects of standards, the impact of standards on society and the economy). The modules and the syllabus I developed reflect this proclivity. This is an important perspective for emphasizing the value of standards and the need to study them, but I believe that it needs to be complemented with an equal--if not greater--emphasis on stakes and trade-offs entailed in standards choices. Hence, when teaching the course next in the fall semester, I would like to build into the curriculum more of the strategic aspects of standard setting. In particular, I hope to include modules related to negotiations, and the dynamics of strategy games. Moreover, because there is shortage of unbiased case studies about standards setting, I would require student to conduct a case study for their final project, and to present it in a multimedia format, which then might become part of the collection of standards modules. (The Syllabus for 2013 is included as Appendix b.)

Overall Assessment

Viewing our project retrospectively, I am quite pleased with what we have accomplished given our limited resources and our personnel problems. I believe that we did a good job of circumventing these obstacles, especially with the development of the standards class and related curriculum. I fully intend to teach *Global Standards; What Are the Stakes?* in the fall 2014 semester, and am exploring ways of gaining adequate support for the production of class flipping modules. It is my intent to have the student develop standards case studies,

I also intend to apply for a grant in the 2014 cycle, which will enable me to bring my project to the next level. If such a grant were received, I would aim to develop the syllabus laid out below (with changes in response to class feedback) into an electronic book, which would entail interactive activities/excises as well as digital modules to illustrate and support the written materials. Depending on resources, I would establish a web-based interface upon which others might contribute to the project. I would dedicate specific staff to carry out both the visualizations and outreach tasks.

Appendix a: Standards Scripts

Standards For Everyone: An Introduction

Welcome to our modular curriculum on standards and standard setting. We call it "Standards for Every One." And I would like to tell you why. What is it about standards that inspired me to develop this program?

Years ago I worked for a Congressional Agency--the Office of Technology Assessment. We called it "Congress' own think tank" Unfortunately, the 101st Congress--notwithstanding OTA's highly acclaimed non-partisan research--decided to no longer fund OTA. It was a great loss.

While at OTA, I was asked to undertake a study assessing the performance of the US standard setting process--a process that I will describe in a subsequent module in some detail. At first I was disappointed in my assignment--what could be interesting about standards, I asked myself? I was in for a great surprise! Thirty years after having finished my OTA report, Global Standards: Building Blocks for the Future (1992), the subject continues to be of great interest to me, as well as source of my research.

Today, what gives me great pause for thought is the fact that there are very few standards courses available within the university community. Nor are there many educational materials that might be used to build such courses. And you could count the number of students interested in taking courses on standards on one hand.

Ironically, this lack of attention to standards comes at a time when standards are becoming ever more critical, given our increasingly complex world. Just consider the banking system; new forms of financial paper are being developed faster than we can develop standards governing their use. Would more and/or better standards have helped to limit the industry's collapse? A good question!

The food industry is also increasingly complex. Notwithstanding labels denoting organic foods, gluten free foods, genetically non-modified foods, and antibiotic free foods, we are somewhat at a loss when trying to sort out prices and ingredients. We all have read, with some horror, about adulterated baby milk in China, and chicken products in the United States. To my chagrin, I find that the 'kibbles' I have been feeding my dog contain ground up animal bones from most any kind of animal--even road kill; intestines and other organs; and the scraps swept up from the food processing floor. Is there not room for standards here?

In trying to understand our limited standards educational tools and facilities, I have asked people in the field how they became involved in the subject. For the most part, they say that they entered through the back door. Trying to solve problems of interest to them, they came face to face with standards. And it was only then that they became involved.

Our curriculum, *Standards for Everyone*, is based on this insight. We look at standards through the lens of different problems, and ask what role standards play both in the cause and the resolution. Hence our curriculum is intended not only for those who anticipate working in the field, but also for those who encounter standards in their daily lives.

Our approach reflects our belief that the tepid interest in standards is due, in part, to the narrow way in which we typically conceive of standards. For example, today, most standards efforts and analyses focus almost entirely on the technical and economic aspects of standards. No doubt, these topics are essential to an understanding of standards and standards processes, and they need to be front and center in any standards course. But these lenses fail to portray the full range of issues to which standards give rise. Standards are ubiquitous--we encounter them everywhere. By extending our frame of reference, and characterizing standards and standards issues more broadly, we can develop materials that attract a wide audience, while at the same time amortize the associated costs across a larger user base.

Given the wide range of standards and standards issues, we cannot create a universal curriculum to satisfy all. So, we have opted for a modular approach that allows educators to pick and choose, tailoring their course materials to their specific needs. Faculty--ranging in

disciplines from engineering, business to sociology, ecology, and English--can use the modules to build an entire course, or simply incorporate specific modules into their diverse course offerings.

Our first modules are prototypes, designed to illustrate the possibilities inherent in a modular approach. We have selected them to illustrate the broadest range of standards and standard setting issues. We have picked our initial modules to illustrate how standards play out in a number of different areas. These include, to name but a few: "Why Study Standards?" "The Standards Universe," Standards: The Coin of the Realm," "Standards: How the West Was Won," and "Standards: The Building Blocks of Life." Focusing on each of these sectors, we address topics ranging from business strategies and innovation to organizational roles, cultural memes, and personal identity.

Standards for Everyone, is built around an open architecture. We hope that you will not only find the content useful in your efforts to promote standards education, but also be inspired by the effort to contribute your own modules. We welcome your engagement in our project.

Why Study Standards?

When is the last time you thought about standards? Chances are the topic only occurred to you when you needed standards, and they were lacking. Maybe you thought about standards when you had to have a three-pronged plug, or perhaps when the sheets you ordered for your mattress didn't fit. Alternatively, standards might have come to mind when you committed a faux pas speaking a foreign language, or maybe it was when you struggled to adjust the shower temperature in a foreign hotel. Herein likes the Standards Paradox: Standards are so essential to our daily lives we typically take them for granted. We seem to value standards most in their absence.

When we do focus on standards, however, we see that they are the basis for--or one might say the interface between--all interactions. As such, standards are the building blocks both of the natural world and society as well as the glue that holds everything together. For, in any given

context, standards constitute an agreed upon set of meanings, scripts, and rules that guide behavior and govern relationships. Embodying critical information in a highly compressed and abbreviated form standards greatly simplify the environment. Signaling opportunities and constraining choices, standards make possible cooperation and coordinated behavior.

Let's just think about the origin of the word standard. It was originally a word that signified a flag or banner that was associated with a given leader, and hence was used to rally his troops in battle (Malone, 1942, 235). Standardized signals continue to play such roles today, even in the animal kingdom. Take slime mold, for example. Instead of rallying warriors to battle, they signal the presence of food, drawing individual slime molds into a cluster, so as to better harvest the meal. Likewise, ants employ pheromones to signal the location of food sources as well as the task that each is performing.

Language and simple gestures play a similar role for the human race. Based on a common understanding, they provide the shared frame of reference and sense of reality that allows us to have intimate relationships and establish common goals. Similarly, cooperation among individuals engaged in interdependent activities is greatly facilitated when people don't act randomly, or on a trial and error basis, but rather conform to common expectations embodied in socially constructed roles. Similarly, organizations gain greater access to resources and reduce their transaction costs, when they adhere to standardized rules and procedures institutionalized in their environments. In so doing, organizations themselves become standardized as the prevalence of bureaucratic forms clearly attests.

In the realm of technology as well, standard specifications and protocols add value to system components by allowing them to interconnect and interoperate in a transparent and seamless fashion. Equally important, when standards serve as identifiers, as in the case of trademarks, they help people sort through extraneous information and make better choices.

In fact, so ubiquitous are standards we ignore them at our period. Just consider what happens to the man who reaches out to pet a dog, even though its hackles are raised?

Similarly, what would you say are the prospects of the student who dresses inappropriately for a job interview? And one can only imagine the sorry sight of the driver who runs a red light.

Mishaps can occur on a large scale as well, and it is just such events that first peaked the public's interest in standards and standard setting. Unfortunate incidents accompanying the industrial revolution provided a major impetus. Thus, for example, boiler explosions averaging 1,400 per year led the *American Society of Mechanical Engineers* to write a comprehensive boiler code in 1910, and to good effect. Once most states and cities had adopted the code, such explosions were virtually eliminated. Likewise, the 1904 leaf fire on the grounds of the National Bureau of Standards had a similar impact. Dealing with the fire was problematic because the fire hoses could not be coupled due to differences in threads. The incompatibility between hydrants and hoses also accounted for the problems controlling the Baltimore fire of 1904. Buildings numbering 1,526 and all electric lights, telegraph, telephone, and power facilities in an area of more than 70 city blocks were destroyed before the fire burned out. Fire companies from outside the area couldn't help becase their hoes were incompatible with the Baltimore hydrants.

Those who discount standards are likely to run into unanticipated setbacks, and forgo good opportunities. For standards have a strategic value in that those who control a standard also control the activities associated with it. Hence standards have been at the center of battles between industry titans seeking control of the market. In fact, the first "standards war" dates back to the turn of the century, when George Westinghouse and Thomas Edison fiercely competed to set the standard for electrical current (McNichol, 2011). Edison went to great lengths to assure that DC current, the basis on which he had built his electrical empire, would trump AC current, which was used by his competitor George Westinghouse. Thus, he engaged in a shameful public relations campaign designed to instill fear in the public about the safety of AC current. To provide evidence for his case, he supported a number of trumped up grizzly experiments involving the electrocution of dogs, cows, and horses. Notwithstanding Edison's efforts, AC current--which could travel further and was more efficient that DC current--won the war (McNichol, 2011).

Such battles continue to be played out--and almost as fiercely--today. The early *browser wars* provide a case in point (Sebenius, 2002). In 1995, Netscape controlled the browser market, with a 90 percent installed user base for Netscape Navigator (Windrum, nd. p. 1). Notwithstanding Netscape Navigator's great lead in the market, the goliath Microsoft, although a latecomer to the game, was able to demolish its rival with a browser of its own--Internet Explorer. Because Netscape Navigator could be employed across multiple network platforms, and be used by software developers to create software for any operating system, it was a threat to Microsoft's dominance in the operating system market (Ryan, 2010). It was only then that Bill Gates stood up and took notice. Determined to squash the competition Microsoft made its browser free to all; it bundled it together with its operating system, thereby loading it on desktops of 50 million new computers each year; and then used its market power to make it the ISPs browser of choice (Windrum, nd, p. 8; Sebenius, 2002, p. 43). As a result, Internet Explorer became the Internet's default browser, as Netscape went into decline. Notwithstanding Netscape's first mover advantage, it could not compete with the financial resources and industry alliances available to Microsoft. It was subsequently taken over by AOL, which later spun the browser off to the nonprofit Mozilla Foundation (Stone, 2008). Today, it has reappeared in a new guise--Firefox.

It is important to note, moreover, that network standards, such as browsers, increase in value the more that they are adopted, due to the growth of networks based on those standards and the externalities associated with them. The Internet standard TCP/IP provides a good example. In the early stages of the Internet's development, there were few adopters, and even fewer commercial providers. However, as the network and the number of applications that it supported multiplied, businesses rushed in to capitalize on the increased value accruing from an open, interoperable standard (Garcia, 2013).

To take advantage of standards benefits, while avoiding the pitfalls to which they might give rise, requires that we have a much greater understanding of them. Our modular curriculum provides a tour of this fascinating standards universe. I hope you will follow along.

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The Standards Universe

Understanding the importance of standards in our lives begs the question of how we can best study them. Precisely because they are ever-present, it is difficult to get a handle on them. To help sort things out, we devote this module to defining standards; scoping out *the standards universe*; and laying out a framework that allows us to differentiate standards for the purpose of analysis.

How we define standards can have major implications. For example, business standard strategies will depend on the type standard at hand. If standards are set by a legislative body, as in the case of the DMCA, businesses will lobby to influence outcomes, whereas if standards are set in the marketplace, businesses will seek alliances with other like minded firms, or--given significant market power--employ competitive economic strategies to control standards outcomes. Similarly, governmental policy decisions will also differ depending on whether one's reference is compatibility standards, safety standards, or environmental standards. For this reason, broad definitions of standards used in everyday speech are not very helpful.

Hence, those who research standards typically formulate their definitions to conform to the specific questions to be asked and the problems to be solved. Economists, for example, generally seek to know how, and under what circumstances, standards are set in the marketplace. They tend to view standards as an agreed upon set of specifications that define a particular product or that allow products to interoperate. Anthropologists, on the other hand, focus on questions of how individual interactions give rise to cultural norms. Thus, they view standards as the accepted rules of behavior that facilitate social interactions. Government policy makers are likely to consider standards as the means to address a societal concern or to achieve a social end. Thus, they often equate standards with regulations.

However, our curriculum--*Standards for Everyone*-- requires an inclusive definition of standards that cuts across a wide array of activities. We need a definition that applies equally to the standard roles that bind organizations together as well as to the standard products, currencies and prices that unify markets. Viewed in the abstract, standards can be said to negotiate the boundaries between diverse phenomena. They provide the rules, or protocols, to be followed in order for objects to interact. Hence we define standards as the *interfaces governing interactions, be they individuals, machines, words, or elements of the natural world.* Accordingly, standard interfaces might govern the mode of interactions; define the conditions under which interactions take place; and/or signify the appropriateness of interactions. For example, to connect to the Internet, one must employ the TCP/IP protocol. Alternatively, to drive on the highways, cars must meet national environmental emission standards. Likewise, to select produce, consumers might look to foods that conform to 'organic' standards.

Notwithstanding their universal nature, standards can be differentiated according to their purposes, as well as by how they are established. We identify three different kinds of standards: control standards, product standards, and platform standards. Likewise, we point to three standard setting mechanisms: a *de facto* process, a regulatory process, and a voluntary consensus process. These three kinds of standards and three different standards processed can be matched to form a matrix, which we have labeled *The Standards Universe.*

The Standards Universe

	Control Standards	Product Standards	Platform Standards
Bottom up/ de facto	Traffic conventions	Popular fads; beanie babies	Language
Top-down/ prescribed	Hours of TV for children	Weights & Measures	Air Traffic control
Voluntary/ negotiated	AMA standards for med practies	Building Supplies	W3C standards

Control standards are designed to constrain interactions either by forbidding an action; by establishing performance criteria that an interaction must meet; or by prescribing the method or design of an interaction. For example, early environmental quality standards on automobiles were design standards: they required that cars be equipped with a catalytic converter. Later standards, based on performance criteria left the design to the automaker, requiring only that certain emission levels not be breached.

Product standards establish the conditions under, and criteria according to, which interactions take place. These standards typically relate to product attributes in terms of their quality, safety, and appropriateness for an intended purpose. A simple example of a product standard is the screw thread standard. The thread is a ridge wrapped around a cylinder or cone, which serves to convert between rotational and linear force. Supporting one of the most prolific machine products produced each year the screw thread standard was first developed as long ago as 1880.

Platform standards define the architecture that links objects one to another in a networked configuration. For example, TCP/IP is the primary standard that governs access to the Internet. Designed as an open standard, TCP/IP has spawned multiple on-line users and uses. Because platform standards are the foundation for higher-level activities, which ride atop the platform, they facilitate innovation. Thus, for example, the World Wide Web was built atop of the Internet platform, while YouTube rides over the Web.

Each of these three types of standards can come about in one of three different ways. Some standards are unplanned; they emerge, from the bottom up, in the context of repeated interactions. For instance, imagine you are walking down the street, and you encounter a passerby coming in the opposite direction. If you are like most people, you will shift your step to the right, as will the passerby (Buchanan, 2003). Based on this learned standard of behavior, ingrained over time, each of you will limit your choice of action to avoid a collision. Such *de facto* standards also emerge in the market place, through iterations of consumer choices or because interested parties have successfully sponsored them. Nature, likewise, gives rise to *de facto* product standards through the evolutionary process of variation, selection, and replication. Thus, for example, flowers give off an electric current that has evolved over time, while the bee has coevolved to recognize the current as signaling the amount and quality of pollen to be harvested from that flower. Platform standards can also emerge from the bottom up, as the development of languages clearly attests.

Many standards are prescribed from the top down by some legitimate authority. Thus, for example, the CEO of a firm can establish the formal roles that employees play, as well as the behavioral expectations associated with them. Such workplace standards are best illustrated in the classic 1955 movie, *The Man in the Gray Flannel Suit*, in which the protagonist, played by Gregory Peck, struggles to maintain his independence in the face of the pressures of a dominant material culture. Governments, operating at all levels, also impose standards in a top down fashion so as to achieve public policy goals. Thus, they may set control standards to regulate emissions, product standards to assure safety, and platform standards to provide for interconnection. The demand for standards often coincides with the emergence of new, advanced technologies. Most recently, for example, the prospect of private drones has led Google to call for privacy standards to regulate them. In the United States, the government relies, when possible, on voluntary consensus organizations to develop standards, which are subsequently mandated by law.

Midway between the market and the government is the voluntary consensus standards process, carried out in the private sector by standards development organizations (SDOs).

This voluntary consensus process resembles top down processes insofar as voluntary standards derive their authority from the consensual process in which they are developed. However, voluntary consensus standards approximate market-based standards in that the influence that participants in the process can exert to promote a standard often reflects their market power. In the United States, the first SDOs emerged to address the problems and issues associated with industrialization. New SDOs were formed in response to specific needs as they arose. Hence they took a variety of forms, and operated independently of one another. Notwithstanding their independence, American standards organizations resemble one another in several ways. In particular, they all arrive at decisions through a process of consensus and provide some level of due process. In addition, they all have mechanisms for participation, comment, and appeal. In contrast to top down, prescribed standards, the adoption of SDO standards is voluntary. However, conformance to such standards is high, given the network externalities associated with a standard that has a wide spread appeal.

This characterization of the Standards Universe provides a reference model for categorizing standards according to the problems they seek to address and the issues to which they give rise. As well, by depicting standards and standards processes according to a variety of dimensions, this reference model provides a basis for drawing new insights about standards based on a comparison of a broad range of contexts in which standards are developed.

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Standards: How the West Was Won

President Theodore Roosevelt's four-volume account, *The Winning of the West* (1889-1896), colorfully details the drama, determination and daring adventures of those pioneers, cowboys, and cavalry who led America's expansion westward. Far less gripping and exhilarating, although no less significant, is the untold story of standards and how, operating under the radar, they contributed to this great westward expansion.

Recall that standards are interfaces that govern all interactions, whether between people, machines, or people and machines. With this idea in mind, picture the vast stretch of territory making up the North American continent. Imagine, then, the boundless number of standardized interactions required to pave the way west. Often *ad* hoc in nature and negotiated *en route*, standards became *the infrastructure*--or platform--upon which, and according to which, travellers journeyed; battles were lost and won; trade was established; and a frontier culture was born.

At the same time, the US westward expansion generated an ever-growing need for standards. As pioneers moved west, they built homesteads, set up mining claims, established general stores, banks, and other small businesses. While located far from the teeming economic activity in the East, these western enterprises were dependent on their far-flung eastern counterparts for supplies, market information, customers, etc. In turn, eastern establishments sought to increase their gains by expanding their markets westward. But, even though trading was in everyone's interest, it was inhibited by a lack of market information and the uncertainties associated with doing business at a distance. Absent a communication infrastructure that could provide adequate east-west feedback, standards specifying product information and the means of exchange, served to reduce uncertainty and thereby greatly expand trade. As trade increased, so did the scope and intensity of interactions, and hence the need for additional standards.

Not surprisingly, given this context, some of the most important standards developed during this period were those related to the communication of market information and the mechanisms of exchange. As the late James Beniger pointed out in his seminal work, *The Control Revolution: Technologic and Economic Origins of the Information Society*, market conditions and prices fluctuated widely from place to place. Lawlessness and opportunism were commonplace. To generate the stable conditions and levels of trust essential for trade to take place, standard economic processes and practices were required (Durkheim, 1893).

Consider the standardized roles of the middlemen who managed the trading process. They were central in this regard. Included among these roles was that of the *commission agent, or factor*, who carried out business on behalf of a merchant in distant markets; *the broker*, who brought buyers and sellers together; *the financiers* who provided a credit network to cover the up-front costs of transporting, processing, and distributing goods, as well as *retailers and other distributors*, such as *auctioneers* and *wholesale jobbers*, the latter being of upmost importance in supplying western retailers.

Equally important were the standardized trading forms and formats that helped to regularize trade by providing greater predictability. Standard invoices, for example, were used to document sales. The bill of lading was employed not only as a receipt, but also as proof of ownership, as well as a negotiable instrument that could be traded for goods or used as collateral to back a loan. Equally significant were catalogs that displayed standardized products, and listed their fixed prices.

Formal institutions, which led to the standardization of business practices, emerged as well. Among these were common carriers--such as the postal service and the railroads, which--operating according to standardized procedures and a fixed schedule--allowed trade to take place on a consistent, periodic basis. Of equal consequence, according to Beniger, was the development of commercial law and legal precedents standardizing corporations; government prescriptions laying out a framework for interstate commerce; the chartering of insurance companies and commercial banks; businesses providing commercial credit ratings, and standardized ways to sort, grade, weigh, and inspect agricultural products, to name a few.

Eighteenth century standards served not only to facilitate east-west trade; by conveying product information, they also provided greater quality control. One of the first product areas to benefit from standards was that of food. For example, responding to scandals in the meat packing industry, Congress passed the Pure Food and Drug Act of 1906. This legislation not only protected against misbranding and food adulteration; it also standardized containers for marketing fruits and vegetables, thereby eliminating false measurements and deceptive shapes.

When employed as trademarks, such quality standards increased the value of goods; they allowed producers to differentiate their products from those of their competitors, and to price products to different markets. To this end, American farmers played a major role in setting agricultural standards. They realized that by grading and classifying their products, they could set up separate distribution channels and increase their profits. Thus, when moving west, farmers labeled their products by their region of origin, while wholesalers used these names--Goschen butter, Genessee flour, and Herkimer cheese--as designations of grade. By the end of the century, these quality standards efforts took the form of branding. Notable in this regard was Henry P. Cromwell's success in packaging and advertising oats, previously considered fodder for animals, as a healthy breakfast cereal using the brand name Quaker (Beniger, 1996).

With the deployment of the telegraph and the completion, between 1851 and 1854, of the four major trunk lines linking the East and West, one might say that the West was finally won. With the advent of steam powered railroads, activities and interactions that had once taken place at a snail's pace were suddenly accelerated, greatly increasing the flow of people, goods, innovations and investments to the West. But, it is well worth noting that the railroads, operating on such a vast scale, could not have played this role without a rash of new standards to alleviate the system's complexity. As described by Beniger (1996), these included not only standardized role assignments and operating procedures, but also innovations such as through bills of lading, standardized cars, uniform standard time, standardized track gauges, as well as standardized automatic couplers and air breaks.

We have seen how critical standards were to the US western expansion. In subsequent modules we will consider how lessons about standards from earlier periods can be applied to our understanding of their role in the expansion of the global economy.

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Standards: The Coin of the Realm

I'm old enough to remember penny candy. When growing up, I was a frequenter at the store around the corner from my house where one could buy newspapers, comic books, soda pops, and, yes, penny candy. While my friends browsed the comics, I surveyed the candies, spread out on the counter much like colorful jewels. My favorites were the sugar dots lined up in rows and columns on long strips of paper. As I nibbled on the dots, making new patterns with each bite, I marveled at the treasure one penny could buy. How things have changed! Today's merchants are often willing to round out a bill just to avoid dealing with pennies. And despite the 'good luck' associated with pennies, people rarely stoop to pick one up.

The changing value of a penny makes one stop to wonder. What are coins? Where did they come from? How is their valued determined? What is their relationship to money? To answer these questions, we need to think, once again, about standards. For coins are standards of value that govern interactions.

Although economists have typically interpreted the value of coins solely in terms of their convenience for market exchange, more recent scholars show that money and coinage are far

more multifaceted than that. In fact, as Andrew Leyshon and Amin Ash (1997) tell us, the origin of coins is rooted not in the marketplace, but rather in social and cultural relationships. As telling, coinage only emerged and was widely disseminated given the rise of centers of power and authority--be they cities, religious institutions, or empires. To understand coinage in its entirely, therefore, we need to assume a more interdisciplinary perspective, one that emphasizes all of the mediating aspects of standards that are described in the module, *The Standards Universe.*

To appreciate the role of coinage as a broad-spectrum standard, let's consider, first, the more narrow, economic perspective, which attributes the emergence of coinage--that is to say, commodity money--to interactions in the limited sphere of the marketplace. I first heard this account, years ago, when studying neoclassical economics based on Paul Samuelson's classic text, *Economics: An Introductory Analysis,* first published in 1948.

In my day, this text served as the font of all undergraduate microeconomic wisdom. In making his case, Samuelson employed a functional argument, based on methodological individualism. Accordingly, he posited that individuals, interacting in the market, and pursuing their own self-interest, logically progressed from bartering goods and services to a trading system based on coinage--that is to say commodity money pegged to a common standard. Samuelson contended that this evolutionary path occurred spontaneously, driven by the desire for convenience, greater efficiency, and a reduction in transaction costs. It is noteworthy, in passing, that the scenario Samuelson described mirrors today's de facto standards process, insofar as it relies, in some form or another, on self-organization, or--one might say--the invisible hand. In so doing, it seeks to explain the past in terms of today's institutional structures--somewhat of a problem, as we shall see.

Samuelson's account has not gone unchallenged, however. More recent, evidence-based, archaeologically and historically oriented scholars point to a number of deficiencies in its logic. These scholars contend that, in contrast to a bottom-up process, coinage was established through a top down process, via the imprimatur of some legitimate authority. Randall Wray's (1999) critique is especially telling in this regard. Noting that choosing a

medium of exchange requires common consent, Wray questions whether, and how, early societies might have coordinated the building of a consensus, favoring one coin over another, especially given the lack of a preexisting market. How, he asks, could an agreement come about, given the broad range of candidate objects ranging from barley, porpoise teeth, sea shells, to various metals, each of which might have served just as well--and often did--as a monetary standard.

Layshon and Thrift (1997) provide an alternative vision. They point out that money emerged in many cases as a means of governing social interactions and cultural practices long before it was used in market exchange. Coins were employed, for example, as bride and blood money, as ceremonial objects, and for religious purposes. Moreover, as Layshon and Thrift attest (1997), the advent of coinage was far from spontaneous; rather it was associated with the rise of institutional structures that could legitimate coins and attest to their value. That explains why minted coins that were guaranteed by governing powers were more highly valued than the actual metal--be if bronze, silver, or gold--that constituted them.

Early Athenian coins, for example, said to be the first commodity coins produced, provide insights about the complex role of coins as standards. The most prominent Athenian coins, the tetradachm were standardized not only by weight but also by the state images featuring the head of Athena on the obverse side and the owl and olive spray on the reverse. These coins were first produced in the mid-sixth century, when an extraordinarily rich vein of silver ore was discovered in the Laurion area of southeast Attica. They served to regulate both social and economic interactions. That these coins were able to serve, equally, as social and economic standards was due in part to their origins in the Greek polis. As Peacock (2006) emphasizes, just as the developing state played a key role in the emergence of coinage, so too did Athenian coinage play a major part in enhancing the legitimacy and power of the state. As the polis gained in authority, taking on both administrative and judicial roles, it laid claim to taxes, as well as allocated money to pay public officials and settle private disputes. To execute its roles in a fair and just manner, the polis needed a standard medium of exchange. What better medium than coinage?

Athenian coinage gained what today's standard experts would describe as a *first mover advantage*. By requiring that all debits and receipts be made in Athenian coinage, the state created a critical mass of users who then became locked-in to the use of Athenian coins. Athenian coinage increased in value not only because of the growing number of users, but also because the state's stamp served as a sign of the coins' redeemability. The popularity of Athenian coinage was enhanced even further, when its standardized form was enshrined in law in the late 4th BCE century under the Athenian Declaration on Coinage And Standards. This declaration required that all coin within the Athenian territory be reminted and converted into Athenian coin. Not surprisingly, by 490 BCE, Athenian mints were mass-producing the tetradachm to meet the growing demand of much of the Mediterranean world. In so doing, they provided a major boost to the Athenian economy. As John Kroll (----) describes it: "Athens' silver industry effectively functioned as an 'industry of money.' " But, even as Athenian coinage promoted trade and development, it also--and as importantly--fostered political unity at home, as well as tremendous political prestige and imperial expansion abroad.

Looking much later at the evolution of coinage in late Iron Age Britain--that is from the late second century BCE to the Roman annexation by Claudius in AD 43--we can gain a better appreciation of the symbolic role that early coins played in integrating a community and sustaining an institutional authority. John Creighton, in his book Coins and Power in Late Iron Age Britain (2002), provides a detailed account. As he points out, Britain in the late Iron Age was characterized by turbulence, due to border incursions from the continent and the rise of an elite group of warring individuals, who together with their *comitatus*, or loyal body of horsemen, jockeyed among themselves for power. The leaders of these groups lavishly bestowed coins and other gifts, such as rings and torcs, on their followers in order to recruit and retain them. Power and influence was thereupon accorded to those who exhibited the greatest wealth and number of clientele. Horses played a central role in the social structure, as attested to not only by a growing equestrian material culture, but also by the imprinting of the man/horse's image, albeit incrementally modified over time, on the series of coins associated with this period. According to Creighton (2002), this image legitimated the leader by metaphorically linking him to the spiritual world. Moreover, evidence suggests that, given

the artistic and technical skill required to mint these coins, their production was carried out through spiritual rituals, practiced over generations and executed by a special class of shamans, such as the druids. As Creighton contends:

> I believe the horse/man image denotes the right to rule through the alliance of a leader and nature, represented by the horse. Since in many ways this is a mystical union, the development of this imagery along lines associated with altered states of consciousness should not be seen as particularly surprising (2002,53)

Looking at the standardization of coinage from an historical perspective provides some useful insights for the study of standardization today. Much of the existing standards literature is theoretical, based on tools that are derived from microeconomics and game theory. Often it seeks to apply universal theories to site-specific problems. The history of the evolution of coinage suggests, however, that standards emerge out of unique social and political contexts, which must be taken into account. Recognizing this fact is evermore important today, as we strive to develop new, cutting edge standards, as for example, those governing financial transactions and interactions, in an increasingly global society.

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Standards: The Building Blocks of Life

We have seen that standards play a central role in every day life. In this module, we explore the role that standards have played in the evolution of life itself. As we shall see, just as living creatures, natural phenomena, and artifacts coevolved in relationship to a changing environment, so too did the standards and protocols that linked them together. In fact, as the complexity theorist Stuart Kauffman tells us in his book, *At Home in the Universe* (1995), it was only by virtue of the standard interfaces inherent in the universe that the diverse entities that comprise all phenomena were able to interact, repair, coevolve, and recreate themselves. According to Kauffman (1995), it is the laws of the Universe, embodied in these standards that have given it its natural, hidden order. Although we are as yet far from understanding all of these laws, we know that they account for the complexity of the universe, as well as signature patterns such as oscillations, power laws, and phase transitions (Beinhocker, 2006). As importantly, these standards provide the platform upon which evolution takes place (Kauffman, 2008).

How did these standards come about, and what role do they play in facilitating life's processes? According to Kauffman (1995), standardized rules, as reflected in the behavior of cells--the constituents of all living things--facilitated the autocatalytic processes that spawned life on our planet. Autocatalysis is a chemical process by which the interaction among chemicals generates a product that is itself a catalyst for the very same reaction. According to Kauffman, given enough diversity among life's elements, all serving as both products and catalysts, and operating according to prescribed rules, life emerged--as in a phase transition--in one fell swoop. With adequate inputs of energy and food molecules, life's processes became self-sustaining.

What about human beings? Where do we fit in? Do we exhibit autocatalytic processes? Do we function according to some preexisting rules? Are we standardized? Well, while we can differentiate ourselves from other species according to any number of variables, we share

many standardized characteristics. One need only reflect upon our anatomical structures. As David Godsell points out in his book, The Machinery of Life, creatures as diverse as birds and mammals, reptiles, amphibians, and fish have similar digestive and nervous systems, as well as an architecture that configures all bones and muscles around a head, torso, and four limbs (Goodsell, 2010). As significantly, when we hone in on the cellular and molecular levels, we encounter an even deeper resemblance among all living things. In fact, it is such commonalities in our make-ups that have allowed scientists to draw inferences and derive insights about human beings based on their research of such diverse entities as plants, animals, and bacteria.

To appreciate the role of standards in the make up and functioning of life, let's look more closely at the cell, where we can grasp a clear picture of a rule-based, emergent order. Cells are non-equilibrium, complex adaptive systems that evolve based on rules, which have evolved, from the bottom up, in response to the actions of their component parts, as well as to their changing environments. Cells are made up of different types of molecules, which are comprised in turn of the atoms carbon, oxygen, nitrogen, sulfur, phosphorous, and hydrogen. Notwithstanding this limited range of materials, these molecules, which are mostly proteins, can combine and recombine in a variety of ways depending on their chemical makeup. Each specific configuration allows the molecules to carry out distinct functions necessary to the survival of the cell. The specifications--or one might say, the standards--for their behavior and replication are housed for the most part in the nucleus of the cell, where they are encoded in nucleic acid, more generally known as DNA (Deoxyribonucleic Acid) and RNA (Ribonucleic Acid).

Looking at the overall functioning of cells, Goodsell (2010) describes them as molecular machines. Like the standardized, interchangeable parts of modern machines, the components of molecular machines connect with each other when their parts--defined by their chemical make up--fit snuggly together. Although molecules encounter one another randomly when swimming in the cell's fluid environment, they only bind together when the interaction is complementary--that is to say, when their interfaces are perfectly matched to a common standard. Proteins serve as enzymes that function to speed up the process. The combinations

and configurations of molecules within the cell are optimized to perform specialized roles. To expand their behavioral repertoires, molecules can be connected to divergent molecules when they are linked together via specific chemical interactions and/or salt bridges that serve--much like a modem in a communication network--to translate between incompatible interfaces. Water in the cell also affects the make-up and behavior of molecular machines. Whereas some molecules are attracted to water, others are repelled by it. Drop a teaspoon of oil in a bowl of water, and you will see what I mean. Depending on how molecules interact with water, they can be attuned to perform specialized tasks.

Of course, one of the most important functions of cells is their preservation and replication. It is here that DNA and RNA--the so-called library of life--play a decisive role. DNA is comprised of two long polymers made up of simple units called nucleotides. These are attached along a backbone made of sugar and a phosphate group. The two strands of DNA, which consist of four bases--adenine (A), cytosine (C), guanine (G), and thymine (T)--line up to one another in opposite directions but in a complementary fashion. Hence, A is always aligned with T, while C is always aligned with G. The specifications, which are encoded in the sequences of these bases, constitute the genetic information that determines the make up and behavior not only of the molecules in a cell, but also the cell's offspring. The code is transferred, read and transcribed by copying segments of DNA into the associated RNA nucleic acid, where it is then translated into proteins. When cells divide, the chromosome, which contain much of an organism's genetic information, are duplicated, so that each new cell contains a complete set of chromosomes with specifications for the unfolding of subsequent cells. The information does not, however, serve as a top-down prescription for the next generation. As Steven Johnson points out in Emergence: The Connected Lives of Ants, Brains, Cities and Software (2001), cells make choices about how to implement the genetic script, based on the activities of other cells in their neighborhood. It is a bottom up, emergent process.

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As we move up the hierarchy of livings things, we observe similar emergent patterns derived from routine, standardized behavior. Consider, for instance, the humble slime mold described by Steven Johnson. Slime molds are amoeba like globular organisms that typically can be

found in the wet areas of the forest on decaying logs, or in piles of leaves on the forest floor. Although slime molds lack cognitive abilities, they respond to their environments in predetermined and predictable ways. When food is readily available they converge and become a single glob; however, when faced with scarcity, they desert the pack and proceed on their own separate ways. How does this happen? Given their limited intelligence, how does the slime mold know when to come and go? You might be surprised. It took scientists some time to realize that there was no central commander in charge to tell the slime mold what to do. Instead, slime mold behavior is a bottom up, emergent process, in which standardized rules and signals are repeatedly at work. Depending on whether there is feast or famine, individual slime molds alter the amount of the pheromone ANP that they secrete, which--much like the switches in a computer--signal to other slime molds which route to take (Johnson, 2001).

Interactions among diverse species likewise exhibit a hidden order based on emergent, rule-based, self-reinforcing behavior. A recent discovery made by researchers at the University of Bristol is illustrative in this regard. Looking at the relationship between flowers and bees, the researchers found that, flowers employ not only their bright colors, the attractive patterns in their petals, and their sweet aroma to romance the bees; they also seek to attract them via their electrical fields. As Young (2013) recounts in his coverage of this new research, bees typically carry a positive charge, whereas flowers carry a negative one. As the bee approaches the flower, the flower greets it with a release of pollen that contains important electronic information about the quality and quantity of nectar to be found in the flower. And by most accounts, bees don't lie! As importantly, once the bee has pollinated the flower, its changes the flower's electrical charge, so that other bees will know that the flower is no longer a good source of pollen.

This type of rule-based, emergent order is ubiquitous in all complex systems; it is to be found not only in all life forms, but also in the ways that organization takes place, be it in ecosystems, the human brain, cities, markets, and technologies--all subjects of other modules in this series. Stuart Kauffman (1995) calls this type of self-organization order for free, and claims that it is essential for evolutionary processes to take place. As he contends, if the

changes brought about by evolutionary selection are not to lead to system chaos, then selection must operate on a platform that is both stable and flexible--that is, order at the edge of chaos--a location that, in fact, evolution selects for.

Understanding the role of standards in the life process yields some important lessons for the study of standards and standardization today. Many studies of standards are presently based on case studies that focus on single component technologies, individual or firm entities, or single standard setting events. Their aim is often to determine how X standard was chosen from among alternative others as well as how businesses might best position themselves in standards processes so as to become more innovative and/or gain a competitive advantage. However, our brief look at life's standards suggests that a more holistic analytic approach is in order. For, just as life emerges from the collective interactions of a wide array of molecules, proteins, etc.--each performing their own standardized roles--so too do technologies, organizations, cities, and cultures. To fully grasp the role of standards, their evolution, and their impacts, we need to paint with a broader brush, one that captures not simple a specific standard, but also its relationship to the standards in its community as well as its environment (Brian Arthur, 2009).

There is an even broader significance to appreciating the role standards play in the emergence of living things. For years, social scientists have struggled to link behavior at the local level to that of outcomes at the global level, but to little avail. One problem has been dealing with complexity and the non-linearity of processes as they evolve over time and in different contexts. Perhaps standards could provide the missing key to linking the micro and macro levels without sacrificing our notions of the complex, hidden order. By identifying the interfaces across diverse boundaries, whether they are cellular membranes or national borders, standards both facilitate and help account for transitions and adaptations over time and space.

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Kauffman, Stuart (2008) *Reinventing the Sacred*, New York, New York: Basic Books.

Young, Ed, "Bees Can Sense the electrical Fields of Flowers," *National Geographic, Phenomena: Not Exactly Rocket Science,* http://phenomena.nationalgeographic.com/2013/02/21/bees-can-sense-the-electric-fields-of-flowers/ , visited June 4, 2013.

Appendix b:
Standards syllabus

Global Standards: What's At Stake?

CCTP 644 Syllabus

Professor D. Linda Garcia
TA: Han Zhang

Thursday: 5:00 to 7:30
Car Barn 317

Office Hours: Tuesday 11:00 - 4:00

Class Overview

Standards affect our lives in many ways. Food and drugs must comply with health standards; cars use standardized interchangeable parts; work places have safety standards; clothing comes in standard sizes; workers perform standardized roles, telephones have standardized interfaces; and bed sheets are sized to fit standard mattresses. Even our lives have become standardized through our reliance on technology. Hence, what standards are adopted, and how they are selected is of considerable import.

One need only consider the stakes involved. Businesses can rise or fall based on the technical, legal, and business process standards to which they must adhere. Exchange standards, monetary standards, and quality standards provide the trust without which trade could not take place. Wars are often fought on behalf of standards, whether religious, political, or otherwise. At the same time, wars are fought in accordance with well-established international standards of conflict, such as the Geneva Convention. Children learn how to speak and how to behave in the context of cultural standards, while adults discover their places in the world based on social standards. Even nature, as we shall see, abides by standards.

Typically we are unaware of standards, because we tend to take them for granted. However, we recognize them all too well when they are absent, and we need them, or when they are not to our liking. This class is intended to unpack the world of standards, that is to say to bring them out of the background and into the foreground. Standards are ubiquitous. Hence, the hope is that, by better understanding the role of standards, and how they come about, students will be able to incorporate this knowledge to their advantage in whatever endeavor they might pursue. Of course, if this inspires a career in standards, that is all to the better! In keeping with the interdisciplinary tradition of the Communication, Culture and Technology program, we will consider standards through a variety of lenses economic,

political, social, cultural, etc. In so doing, we will consider the standards universe as a complex system, in which non-linear processes often lead to unintended, but significant, consequences.

Course Requirements

This class calls for a significant amount of reading, research, and class participation. In addition, students will be asked to write weekly blogs, identifying and characterizing a standards-related issue that appears in the weekly news. As well, as a final project, students will be called on to write a paper, based on a significant problem in which they are interested. As we will discuss in class, standards serve to address problems; hence, in their papers students will posit a problem as well as possible solutions for it; describe the role that standards might play with respect to it; speculate about the path that might lead to the necessary standards; and identify the potential trade-offs and unintended consequences that might be associated with such a standard/solution.

Readings are drawn from the following books as well as a compilation of papers made available to students via blackboard on-line. There will be no midterm in this class; instead students will be graded, in part, based on their understanding and interpretations of the readings as exhibited by their blogs and their participation in class. Students should feel free to use the office hours to get feedback as to their participation in the class. Grades will be apportioned as follows: Class participation 1/3; weekly blogs 1/3; final paper 1/3.

Books to Be Purchased

Arthur, Brian (2009) *The Nature of Technology: What It Is And How it Works*, New York: Free Press

Beniger, James (1986) *The Control Revolution: Technological and Economic Origins of the Information Society*, Princeton, NJ: Princeton University Press.

Grewal, David Singh (2008), *Network Power: The Social Dynamics of Globalization*, New Haven, CT: Yale University Press.

Denardis, Laura, ed. (2011) *Opening Standards: The Global Politics of Interoperability* (Cambridge, MA: MIT Press).

Frank, Robert H. (2012) *The Darwin Economy. Liberty, Competition and the Common Good (paperback)* Princeton, NJ: Princeton University Press.

Weber, Steven (2004) *The Success of Open Source*. Cambridge, MA: Harvard University Press.

Winner, Langdon, *The Whale and the Reactor: A Search For Limits in an Age of High Technology*, Chicago, IL: University of Chicago Press.

Session One: Why Standards?

In this class, we will provide an overview of the class, and lay out the schedule of classes and assignments. We will share expectations about the class, and describe the basis on which grades will be assigned. Students will be asked to describe their interest in standards, the role that standards play in their lives, and the occasions in which they must deal with them. As we shall see, and as Lawrence Bush points out (see readings) standards are ubiquitous. A question we will address in this class is WHY? One answer is that standards emerge and are adopted to solve problems. But as we shall see the standards solutions we select to solve problems are not necessarily optimal. Moreover, they have costs as well as benefits, because they eliminate alternative solutions and generate new problems, which require new standard solutions in turn.

Required Readings

Busch, Lawrence (2011) *Standards: Recipes for Reality*, Cambridge MA: MIT Press, Introduction, Chapter one.

Langdon Winner, Technology as a Form of Life," and "Do Politics Have Artifacts," in Langdon Winner, *The Whale and the Reactor*, chapters 1, 2 & 4.

Session Two: The Standards Universe

Standards are ubiquitous, varied, and contextually grounded, so it is difficult to conceptualize them in their entirety. Depending on what standards we are talking about, we might define them very differently. In this session, we shall compare definitions, discuss the ways in which standards are similar and different, and establish an approach that allows us to categorize standards by type as well as to consider the standards universe as a whole. This approach allows us to more clearly identify the impacts of standards as well as the conditions under which such impacts will likely occur.

Required Readings

Busch, Lawrence, "The Power of Standards," chapter 2

Garcia, D.L. "The Standards Universe"

Session Three: Setting Standards

As we have seen standards can come in many forms, and can be set in any number of different ways. In this session, we will look at how such standards come about. In particular, we will view standard setting as a complex process that cuts across micro, mezzo, and macro levels. To incorporate these levels into a unified approach, we will focus our analysis on the notion of "organizational fields." In addition, we will describe how such fields are determined in part by

their larger social, economic and political environments. Looking at the micro level, we will view standard setting in terms of communities of practice as well as Actor Network Theory (ANT).

Required Readings

Garcia, D. Linda, "Standards for Standard Setting" (posted on black board).

Garcia, D. Linda, Leickly, Bethany, L. and Willey, Scott, *Public and Private Interests in Standard Setting: Conflict or Convergence*.

Garcia, D.L. and Burns, Kelsey, *Globalization, Developing Countries, and the Evolution of International Standard Setting Communities of Practice.*

Session Four: Standards as Infrastructure

Infrastructure can be defined as foundational material and social structures, or one might say platforms, that support life's on-going activities. When infrastructure is conceived as such, we can see how standards constitute infrastructure. Like most infrastructures, standards are typically taken for granted, and hence hidden from view. In this session, we will bring them to the foreground, highlighting the key role they have played in supporting and sustaining various aspects of life.

Required Readings

Huler, Scott (2010) *On the Grid: A plot of Land, an average neighborhood, and the systems that make our world work*, chapters 1 & 2, (posted on blackboard).

Beniger, James (1996). *The Control Revolution.*

Hounshell, David A. *From the American System to Mass Production: 1800-1932*, Forward, Chapters 1 & 6

Garcia, D. L. "Standards: the Building Blocks of Life,"

Session Five: Standard Wars

Picking a standard implies rejecting the alternatives, generating in the process winners and losers. Hence the selection of standards is often a very contentious affair. Moreover, because the outcomes of such battles are typically a product of strategic firm behavior, their outcomes are not necessarily optimal. As importantly, decisions taken early on in the standardization process are subject to path dependence and increasing returns, so false starts often become locked-in. In this session, we will look at some examples of standards battles as well as the economics behind the firm strategies that led to them.

Required Readings

Besen, S. and J. Farrell (1994) "Choosing How to Compete: Strategies and Tactics in Standard Setting, " *Journal of Economic Perspectives*, 8: pp. 117-131

David, Paul A. "Path Dependence, its critics and the question for 'historical economics.'

Farrell, Joseph and Garth Saloner, "Competition, Compatibility and Standards: The Economics of Horses, Penguins, and Lemmings, " University of California at Berkeley, Working Paper 94720.

Sebenius, James K. "Negotiation Lessons From the Browser Wars," *Sloan Management Review*,

Stango, Victor (March 2004) "The Economics of Standards Wars," *Review of Network Economics.* v.3, issue 1

Session Six: Standards: One Size Fits All?

We have seen from our readings of James Beniger how standards served as solutions to the growing complexity of society. Precisely for this reason, standards served to reduce alternative possibilities. In the process, the winning standards, by defining reality, take on a life of their own. In this session, we will look at the social construction of behavior via standards in a variety of realms.

Required Readings

Hanseth, Ole and Eric Monteiro, "Inscribing Behavior in Information Infrastructures."

Jordan John M. *Machine Age Ideology: Social Engineering and American Liberalism, 1911-1939*, chapter 1 & 2.

Lengwiler, Martin, "Double Standards: The History of Standardizing Humans in Modern Life Insurance,"

Meyer, John W and Brian Rowan, "Institutionalized Organizations: as Myth and Ceremony, *American Journal of Sociology,* v. 83, n. 2, September 1977. JSTOR, can be accessed on-line.

Session Seven: Standards and the Power of Networks.

Standards embody power not solely by virtue of their ability to define reality, as Lawrence Busch has argued, but also because of what Grewal characterizes as 'network power.' As he argues, networks exhibit externalities, which result in winner take all outcomes. To be excluded from a network, then, is very costly. When the costs are very high, we have little

choice but to conform. Grewal relates the problem of network standards to globalization, and shows how network power is prevalent not only in technology networks but in all social relationships. To counteract the type of network power that arises in the context of 'sociability,' Grewal calls for a greater role for 'sovereignty' in standards development. A very interesting, and provocative, position, but one that is very relevant to global governance.

Required Readings

Grewal, David Singh (2008), *Network Power: The Social Dynamics of Globalization*, New Haven, CT: Yale University Press.

Session Eight: Standards and Interoperability

Networks are increasingly important as the world becomes more and more interconnected. Standards not only allow for their interconnection; they also serve to determine their architecture and the social structures that derive from them. Control of network standards is therefore a tremendous strategic resource. The growing importance of networking has been accompanied by calls for open, interoperable networks. At the center of the debate is the tradeoff between the benefits of openness, which take the form of numerous externalities, and the economic benefits to the firms that hold proprietary technology. Striking a balance is at bottom a political issue. In this session we will trace the issues and arguments underlying this issue, and discuss how--as in the case of net neutrality--they play out in major policy debates today,

Required Readings

Garcia, D. Linda, Kale, Madhura, and Danish, Sara, "Structural Strategies for Promoting Network Interoperability through Openness

Dinardis, Laura, ed., *Opening Standards,* pp. 135-237.

Wu, Tim, *The Master Switch*, New York, NY: Vintage Press, chapters 20 and 21

Garcia, D. L. "The Evolution of the US Internet, a socioeconomic account.

Session Nine: Standards and Innovation

As Brian Arthur reminds us, today's innovations are the product of previous technological developments. Just as the pieces in a Lego set have standardized interfaces that allow them to be put together in any number of ways, so technology modules must be interoperable if they are to build upon one another and be reconfigured in new innovative ways. As we have seen in the case of the internet, innovation does not only take place when technologies interoperate, but also when people, knowledgeable about technology, interact and provide feedback in a cumulative interoperable fashion.

Required Readings

Arthur, Brian (2009) *The Nature of Technology: What It Is And How it Works*, New York, NY: Free Press

Murray, Fionam and O'Mahony, Siobhan, "Exploring the Foundations of Cumulative Innovation: Implications for Organizational Science"

Session Ten: Standards and Complexity

As we have seen, standards and the present mode of standard setting emerged in the context of the Industrial Revolution. Standards were viewed as a means of reducing the complexity of the age brought on by the quickening pace of life, which resulted in part from the many advances in information and communication technologies. The development of standards, in turn, gave rise to new business practices and organizational forms. Today, we are once again witnessing major changes in information technology accompanied by the growing complexity associated with a globally networked economy. Not surprisingly, new standard setting practices have emerged, which--if history is any guide--will likely have repercussions for how we organize our social and economic activities. One powerful alternative to the traditional standards practices is the 'open source movement.' In this session we will examine the open source process, open source standards, and their implications for economic and social practices in the future.

Required Readings

Weber, Steven, *The Success of Open* Source, Cambridge, MA: Harvard University Press.

Session Eleven: Standards, Trade and the Global Food Chain

In the United States, concern about food safety arose with the publication of Upton Sinclair's famous 1906 novel, *The Jungle*, in which the author documented the abominable conditions in the meat packing industry, and the food safety hazards associated with them. One result of the public uproar engendered by Sinclair's novel was the establishment of the Food and Drug Administration. Of course, as we can see from recent events, the problem of food safety did not end there. In fact, today the problem is compounded by the existence of a global economy in which food products not only constitute a large segment of international trade, but are also part of a vast chain of events, which are subject to various standards, and difficult to monitor. In this session, we will examine the relationship between food safety, government regulations, and international trade policies.

Required Readings

Adrie, J.M. Beulens, et al, "Food Safety and Transparence in Food Chains & Networks: Relationships and Challenges

Marian Garcia Martinez, et al. "Co-regulation as a possible model for food safety governance; Opportunities for public-private partnerships"

Laurian J. Unnevehr, "Food safety issues and fresh food product exports from LDCs"

Spencer Henson and John Humphrey, "The Impacts of Private Food Safety Standards on the Food Chain and on Public Standard Setting Process."

Jean C. Buzby, "international Trade and Food Safety: Theory and Case Studies

Wilson, John S. and Tsunehiro Otsuki, *Global Trade and Food Safety, Winners and Losers in A Fragmented System*.

Session Twelve: Global Standards and Global Politics

In the domestic arena, standards battles are typically played out in the private sector, as firms seek to build market alliances on behalf of particular standards. At the international level, however, global politics are at stake. Standards serve not only to determine market power, but also the distribution of power among nation states. In this session, we will examine the role that international standards play in determining the power relationships among international actors.

Required Readings

Stiglitz, Joseph, *Globalization and Its Discontents*

Denardis, Laura, Protocol Selection as Power Selection, in *Protocol Politics*

Session Thirteen: The Smart Grid: A Public-Private Partnership

Building out the smart grid is a key element in the Administration's plan to provide lower cost energy for consumers, to achieve energy dependence and to reduce greenhouse gases. It is a complex undertaking, requiring input and cooperation from a variety of players. Moreover, its success depends on achieving interoperability. In this session we will examine how government partnered with the private sector to bring this effort forward. The success of this undertaking suggest the circumstances under which government private sector partnerships in standard setting are most fruitful.

Required Readings

Vehbi, C. Gungor, et al. "Smart Grid Technologies: Communication Technologies and Standards,"

Report to NIST on the Smart Grid Interoperability standards Roadmap

DeBlasio, and Cherry Tom, "Standards for the Smart Grid."

The Future of the Electric Grid, MIT Report.

The U.S. Smart Grid Revolution: Smart Grid Workforce Trends 2011.

Paths to Smart Grid Interoperability, A Smart Grid Policy Center White Paper,

Sood, V. K., "Developing a Communication Infrastructure for the Smart Grid,"

Session Fourteen: What Role For Government?

A common mantra in the United States is: "What's Good from General Motives Is Good For the Country". This attitude is extremely prevalent in the standards arena, where most participants argue that: "we can do it best on our own." Throughout the course we have seen occasions in which Government has played an important role in standards development. Under what conditions might this be the case? We will explore this question in our final session, as well as consider Frank's argument that 'what's good at the micro level,' is not necessarily good at the macro (societal level). This should be a good conversation.

Required Readings

Robert H. Frank, *The Darwin Economy. Liberty, Competition and the Common Good*