This paper was published in *The International Journal of IT Standards and Standardization Research,* Vol. 5 No. 2, July-December 2007.

Teaching Standards to Engineers

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BIOGRAPHY:

Ken Krechmer (krechmer@csrstds.com) has participated in communications standards development from the mid 1970's to 2000. He actively participated in the development of the International Telecommunications Union Recommendations T.30, V.8, V.8bis, V.32, V.32bis, V.34, V.90, and G.994.1. He was the technical editor of Communications Standards Review and Communications Standards Summary 1990 -2002. In 1995 and 2000 he won first prize at the World Standards Day paper competition. In 2006 he won the joint second prize in the IEC Challenge Contest. He was Program Chair of the Standards and Innovation in Information Technology (SIIT) conference in 2001 (Boulder, CO) and 2003 (Delft, Netherlands). He is a lecturer at the University of Colorado, Boulder, CO, USA and a Senior Member of the IEEE. His current activities are focused on research and teaching about standards.

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ABSTRACT

This paper focuses on the training needed by technical experts and explores the type of academic coursework as well as training that technical experts need in the field of standards and standardization.

KEYWORDS
standards education, standardization education, isology.

INTRODUCTION

Standardization has been practiced for a long time. Until recently, the people who attended standardization meetings were predominately trained in the technical field associated with the standardization efforts. As the Internet has become more important to all of society, more people recognize the importance of standardization; some Internet standardization activities (e.g., ICANN) now attract significant non-technical participation. Standards impact many fields (e.g., law, economics, business, etc.), creating functional standards in every area requires experts in that area (termed technical experts). This paper focuses on the training needed by technical experts, sometimes called engineers, and explores the type of academic coursework as well as training that technical experts need in the field of standards and standardization.

Successful technical courses are quite different from successful non-technical courses. Lucky (2006) states that, "We engineers are used to building on the foundation of a relatively small set of rules - Maxwell's Laws are the proto-typical example - where everything can be reduced to the application of a few equations. This kind of ordered world fits very nicely into textbooks and test questions." Some existing standardization courses focus on technical students successfully (see below), but no existing standardization courses describe standardization using a relatively small set of rules where the use of such rules allows inference into future system behavior.

The current focus of standards and standardization education is on standardization, the process of creating, implementing or using a standard, usually with examples of different standardization processes. Such courses do not offer the student a theoretical basis to understand standards and standardization. A "standard" describes a concept or realization based on common agreements. The concept of a standard may be described by a small set of rules based on set theory (Krechmer, 2005). While learning about standardization is desirable, as it offers insight into the importance of standards in every technical and commercial field, this short paper argues that academic courses would be better to focus on teaching the theoretical rules that underlie standards and use specific standardization examples for demonstration that the rules function as proposed.

With the view that there are basic rules that systemitize it, the disipline of standards and standardization is a science and thus can be termed *isology* - the science of standards. The author argues that studying the science of standards is an academic endeavor while creating standards is a practiced skill.

REVIEWING STANDARDIZATION EDUCATION WORLDWIDE

A 2003 European survey on standardization education, Acyl (2003) states, " ...the survey shows that very little effort is done in Europe related to standardization training and Education [sic]. It also shows that although standardization is above all an issue of business more than a technical issue, Business Schools are not in general involved in any curriculum or session in a curriculum on this matter. More important, it appears a general feeling of lack of understanding about the subject itself [sic]." Courses with some standardization focus identified in this survey include IT Security, Quality Engineering and Software Engineering.

In a report on the Standards Education in Korea - University education program, Kim (2006a) indicates that a common standardization course is given in 35 technical universities and has achieved an enrollment of 2,639 spring semester and 2,323 fall semester students (roughly 100 students per course in 2005) with a good satisfaction rating from the students. Initially the courses suffered from low enrollment, but recommendations from previous students, some publicity and the course being required by the engineering schools increased enrollment (Kim, 2006b).

A course on Strategic Standardization was offered jointly by the School of Law and the School of Engineering at Catholic University Washington, DC from 1999 to 2001. In three years, 18 students attended. The course was then discontinued (Purcell, 2003).

In a US engineering school survey in 2004 (Center for Global Standards Analysis, 2004), the major findings were:

1. Standards education is not a priority issue among schools of engineering in the United States;
2. Schools of Engineering in the United States do yet not accept the critical nature of standards in the new 21st century global economy.

A survey of standards-related education in Japan conducted by Kurokawa (2005) of the Science and Technology Foresight Center, identified 28 different universities with current standardization courses. These courses are focused on technical students and include lecturers from local standardization organizations. The survey's author also indicates that the Chinese have a program of standardization education similar to the Koreans.

At two universities in the Netherlands which teach a standardization course, each course attracts between 10 and 30 students per year. The professor teaching the courses notes the difficulty in attracting students to a course in standardization (deVries, 2005, p. 80).

For further standardization course examples see the EU's European Commission (2006) catalogue of academic institutions involved in research and training related to standardization.

Reviewing these surveys in more detail suggests the following:

- The focus of most of these academic courses is on standardization in a specific functional area, industry or market segment.
- Academic standardization courses on specific standardization areas such as: metrology, IT security, safety standards, software engineering or quality have little in common.
- Even considering the academic courses, most standardization training is done by the hundreds of existing individual standardization organizations.
- The Korean courses success appears to be due to its focus on engineering students and inclusion in technical curriculums.

Throughout the course of history, the functions of standards have evolved. As the importance of measurement standards to increase trade became more obvious, measurement standardization often became regulated by governments. The expanding need for new standards as the industrial revolution developed, gave rise to commercial standardization. Both a governmental interest in standardization and a commercial interest in standardization are realistic. Many countries continue to view standardization as a governmental issue. The United States government tends to consider standardization a commercial issue as standardization is seen as a means to achieve commercial ends (Congress of the United States, 1990). This view might be one reason for the limited academic interest in the field in the United States.

THE PROBLEMS WITH TEACHING ISOLOGY TODAY

The possible effects of standards are very broad and include expanded communications, increased quality and decreased cost (for the manufacturer, service provider and consumer), increased trade (local, regional and international), increased uniformity, new markets (innovation or location), information dispersion, market control and regulation. The widespread use of standards increases compatibility, interchangeability, interoperation and usability. In micro-economics literature, the impacts of standards have been identified as coordination, scaling and learning, network, and gateway effects (Arthur, 1988). All these different effects may have significant ramifications on society. And these effects expand as technology becomes more critical to society. Trying to comprehend such a broad range of effects without an effective model of the causes is not realistic. This is one more reason for the low interest in the West in existing standardization courses.

The models and rules that apply to all standards and every standardization process are still developing. Recognizing that every standardization process can be seen as anticipatory, participatory or responsive relative to the appearance of products and services is recent and just beginning to be supported in the literature (Baskin, 1998). The idea that standards can be seen as a series of successions over recorded history with each succession having a different form of economic impact is new (Krechmer, 2000). Recognizing that the concept of a standard can be defined in mathematical terms is still contentious (Krechmer, 2005). Whether or not these specific theories are valid, the lack of widely accepted models and rules that offer insight into the field seriously diminishes the value of academic training in the discipline. The standardization disipline "will never truly establish itself as an academic disipline in its own right until those that profess the subject demonstrate that it is capable of developing, and has developed, its own theoretical foundations." (de Vries, 2002)

The lack of agreement on the models and rules underlying standards and standardization has many ramifications:

- Definitions of the terms standard and standardization are not agreed or rigorous.
- Reference standards, metrology standards, manufacturing standards, and Information and Communications Technology (ICT) standards are not linked together as a unified discipline.
- The relationship between economic theory and standards theory is not developed sufficiently to allow the total economic effect of each of the different standards to be quantified.
- The necessity of a priori agreements, which may be standards, for any communications is not widely understood.
- There is no broadly accepted theory explaining the layered nature of standards (Verman, 1973).

The lack of such basic definitions, rules and models is a major reason that:

- There is no text book addressing all the different standards including reference, metrology, manufacturing, and ICT which introduces a unifying theory, develops common rules and models, offers examples of how the theory applies to all different standards and provides problem sets for the student.
- Standards concepts are often not included in the other disciplines they strongly impact including: business, strategic management, engineering, science, micro-economics, patent law, history of technology, public policy and social sciences.
- There is no succinct understanding of the importance of standards and standardization in the general population.

Academic courses are needed to address the importance of standards, provide theory to allow analysis of the field as well as identify what students should be aware of in their field of interest.

Sometimes young engineers do not consider carefully enough the requirements, specified in public standards, for the functions they are designing. Training to consider applicable standards needs to take place within existing engineering courses, while an elective course, perhaps at a graduate level, would focus on teaching the general concepts that apply to both standards and standardization. Training within existing engineering courses would, as a byproduct, identify standardization as an important activity in each affected field. Then the student who has further interest may be motivated to take additional courses that focus on isology. This view is supported by other researchers in the field. (deVries, 2005, p. 77-78).

Hayek (1973) notes that standardization may occur by accident, assumption, convention, committee or fiat. In the cases where standardization is a committee effort, the give and take of standardization under the procedures of a specific committee is a practical art learned by reviewing the committee's training materials or attending meetings. Many engineers, the author included, have learned the practice of standardization by going to specific standardization meetings and participating in the work.

Of course, an introduction to a specific process of standardization is desirable for new standardization participants. Many standardization organizations now make available materials to teach new participants how their specific standardization committees function. Considering how little overlap there is in policy and procedures between different standardization organizations, ISO and the ITU as example, it makes little sense to learn about the operation of a specific standardization organization before there is a desire to participate.

Teaching the practice of standardization is valuable only when applied to a specific standardization process. Practical training in specific fields of standardization may not be very useful to technical students as most engineers are well advanced in their careers before they become active in standardization work. All professional people desire to learn the rules that apply to their discipline. Without an understanding of the rules of isology, the student does not acquire the tools to analyze either the impact of different standards or how future standardization actions may impact their field of endeavor. For isology to offer serious training to technical students, rigorous rules and models are necessary.

THE PROCESS OF STANDARDIZATION

Standardization is the selection part of a system which creates variations and makes selections - just like an evolutionary system.(Darwin, 1895) Evolutionary systems function to increase the likelihood of survival by minimizing risk, rather than reducing the total energy used. In the standardization process different standards proposals are often combined into a final standard so that each proposal "survives," which is not always energy efficient but may be standardization efficient.

Currently engineers are trained to create efficient designs, not minimize risk. Minimizing risk requires a very different approach from creating efficient designs. Teaching engineers the need to balance these different goals is an important task of isology education. Important enough that students are likely to recognize the need to learn it.

Balancing the multiple interests represented in a standardization committee requires some form of fair standardization. Each standardization participant must find their interest acceptably represented before they can agree to a new standard. In this light, the concept of the "best" standard does not really exist. Standardizing two or more ways to achieve the same result, while less energy efficient, may minimize both short term risk (meaning that the standard is more likely to be completed) and long term risk (meaning that two or more ways to achieve the same result provides options should one way turn out to be less desirable in the future, e.g., due to higher royalties). Choosing how to balance multi-party interest and single standard efficiency is often the most difficult task in a standardization process.

An example of the need to balance efficiency and interest is a "standards war," when two different technical approaches to a standard vie to be defined in the standard. Standards wars usually occur when the different technical approaches represent value to different organizations or groups of organizations. The public does not care about who wins a standards war. The public only cares about receiving the product or service that a needed standard helps define (Shapiro, 1999).

A standards war pits two or more technical approaches against each other in competition to be included in an eventual standard. Usually a single standard is considered a goal to reduce inefficiency and cost. However computers (e.g., in cell phones or PCs) are changeable and can therefore allow multiple choices. One example is support for both the Mozilla and Microsoft Internet Explorer browsers in a single personal computer. Where it is economically practical to support multiple implementations of the same function, when a standardization organization deadlocks over the technical approaches, the choice should be to include all the economically acceptable variations. Such a choice can offer a balance between efficiency and commercial interests.

Hesser (1998) describes standardization as a tool in the service of society. This is the basis of the view that only sanctioned standardization bodies produce standards. Sanctioned standardization bodies are considered to operate for the good of society. Private or non-sanctioned standardization organizations are assumed to operate for private gain, not public good. This is a narrow view. Even while respecting the public good, standardization often entails choices that favor some and reject others. Such choices are made in sanctioned standardization committees as well as private consortia, the only real difference is the procedures used to make the choices. Standardization, the process of creating, implementing or using a standard, may be a service to society, but it also creates winners and losers.

Successful standardization entails a recognition that the "best" may be what is politically possible rather than what is technically most efficient. In standardization today the idea of "the politically possible" is fraught with negative connotations. It is more productive to understand as the solution that provides the lowest risk to the largest number of participants.

TEACHING STANDARDS

Focusing on the rules and models underlying standards rather than the process of standardization will create more compelling academic courses that are more directly related to the interests of technical students. While isology is a cross-disciplinary science, the creation and implementation of technical standards is the practice of scientists, engineers and technicians. It is the use of technical standards that impacts aspects of other fields such as business, economics and law. Other academic fields which may study standardization include social sciences, the history of technology and public policy. Non-technical students should learn how the concepts underlying standards and standardization impact their field. Technical students should be introduced to the practice of standardization as part of their specific technical curriculum. Then academic courses on isology should be available for those who wish to study the field in more depth.

Some standardization courses are fragmented by attempts to address in a single course three real, but separate, needs:

1. Teaching a non-technical audience the importance of standards. Attendance demonstrates that teaching a non-technical audience the importance of standards is often unsuccessful. Non-technical students usually do not see a need to learn about standards. As technical students become increasingly interested in isology other students will recognize the value in understanding the discipline.
2. Teaching technical students what they need to know about standards in their field. This requires a technical course. Such courses currently seem to be the most successful. Serious technical students are often not interested in non-technical courses.
3. Teaching the policy and procedures of individual standardization committees. This is only valuable to people who are planning to attend specific standardization committees in the near future.

Teaching technical students about isology should occur in two phases. First, an introduction to the subject should be a part of existing technical courses. A big gap in existing isology education is the paucity of discussion of the general field in secondary and undergraduate technical courses. Few physics courses address the importance of standards for mass, time and space to the understanding and use of all physical phenomena. Trade and technical courses often do not address the importance of specific standards in each trade or technology. Standards are perceived much like air, necessary but not noticed, in technical education today. It is in such trade and technical classes that a recognition of standards and their impact on modern society should be first presented. With such introductions to isology it is reasonable to expect an increased interest in higher level, specific courses on isology.

The second phase of isology teaching would be a separate technical course developing and explaining the rules and models that illuminate isology. One successful approach to teaching a technical discipline has been termed the Modeling Method which has the following objectives:

- "To engage students in understanding the physical world by constructing and using scientific models to describe, to explain, to predict and to control physical phenomena.
- To provide students with basic conceptual tools for modeling physical objects and processes, especially mathematical, graphical and diagrammatic representations.
- To familiarize students with a small set of basic models as the content core of physics.
- To develop insight into the structure of scientific knowledge by examining how models fit into theories.
- To show how scientific knowledge is validated by engaging students in evaluating scientific models through comparison with empirical data.
- To develop skill in all aspects of modeling as the procedural core of scientific knowledge."[1]

Following the Modeling Method, the curriculum of an academic isology course would develop the basic model of standards (successions) correlated with mathematics, history and economics, the basic concepts (evolutionary processes) behind standardization, as well as examples of the practice of standardization to illuminate the theory. Analysis of the impact of standardization in a specific technical discipline should be included in the appropriate courses in that discipline.

If academic courses in the field are to be successful, they need to attract and provide useful training to scientists, engineers and technicians. This requires acceptance of and instruction in models describing standards concepts and standardization processes, as well as validation by experimental evidence.

VALUE TO THE STUDENTS OF ISOLOGY

The creation of standards worldwide has become a large, rapidly growing field employing more than a half million people at least part time.[2] Many of the most successful companies in the high technology markets control key standards relating to their markets. Controlling patents that apply to a successful standard in the market has become a means to demand very large payments. An example of such very large payments is the Research in Motion (producers of the Blackberry) royalty payment to NTP (a patent holding organization) of over $600 million. College students are often interested in entering a field with financial promise. Standards increasingly impact the market success of every technical product. At the intersection of business, law and every technology, isology is a promising new field.

Technical students who wish to focus on this new field may find direct employment with: research organizations developing new technologies which will require new standards, development organizations bringing new products and services to market that need to implement existing or create new standards, production organizations which can benefit from their own standardized use of various products and services, government agencies that support the introduction or use of standardized products and services, or standardization organizations themselves.

Students with interest in a specific technical field will find that an involvement in standards and standardization brings opportunities for greater industry visibility and senior level technical positions. In addition, students from business, law, economics, social science, public policy and history of standards will find that studying isology offers new ideas, insights and direction in their field. The study of isology is a multi-disciplinary science. Multi-disciplinary fields provide some of the fastest growing employment opportunities.

THE FUTURE OF STANDARDS AND STANDARDIZATION EDUCATION

Current academic courses on standardization have not been as successful as desired. This may be improved by greater focus on the technical aspects of the discipline and greater integration of standards concepts in specific technical courses. Once accepted models and rules are available and verifiable, then a formal technical education in standards and standardization can develop and academic courses of interest to technical students can emerge.

Training current and future teachers and professors of technical courses to recognize the importance of standards to their students may take time. To accelerate the process, these teachers should be among the first students of each new isology class. Perhaps a web-based course on isology promoted to existing teachers of technical curriculum would be helpful, a first attempt is a standardization course developed by four Asian and two European universities offered by the Helmut Schmidt University Hamburg, Germany (http://www.standardization.de/_sites/_e-lehre/standardisierung_en.htm).

Once the rules underlying isology are identified, the scientific nature of the field becomes clear. Now an area that has been seen mostly as an application, rightfully becomes a discipline of its own. This opens the discipline to new and much needed research as well as attracting students who find technical subjects interesting and challenging. The science of isology has much to teach us all.

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has been supported by grants from the National Science Foundation from 1989 to 2005. The documented success of the workshops and the enthusiastic response of the teachers has stimulated institutionalization and expansion of the program through increased involvement of university physics departments.

2 The author makes this estimate based on 30 major standardization organizations worldwide with the largest having 30,000 participants. For example, the IEC has 10,000, the IEEE 20,000, VDE 33,000, and the ASTM 30,000 based on their current web site information. Estimating that an average sized, major standardization organization has 15,000 participants, then 30 x 15,000 ~ 500,000.