Development of a CD-ROM Metrology Course at NIST

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Abstract

Introduction
The NIST Weights and Measures Division (WMD), formerly the Office of Weights and Measures (OWM), conducts training in mass metrology at Basic, Intermediate, and Advanced levels. Over the years, the demand for these courses greatly exceeded the availability. In addition, requests are regularly received to provide refresher training and to provide training on-site. Available resources are not adequate to meet the number of requests. In view of the needs, WMD decided to develop a CD-ROM training course and to transfer the contents of a one-week hands-on course to an interactive, multimedia CD-ROM metrology course that would include interactive activities, knowledge checks, examples, video demonstrations, and numerous specialty graphics and photos.

This paper presents 1) background information about the project, 2) an overview of the NIST Weights and Measures Division Basic Mass Metrology Seminar, 3) the process used for content development and review (from the original request for proposal and project description to final product review and delivery), and 4) numerous lessons learned during the development of the course. The course material is being translated into Spanish for even wider distribution and metrology support.

Project Background

Targeted Audience for this Project
The specific audience for this course consists of metrologists working in various types of mass calibration laboratories. There are approximately 110 metrologists in State weights and measures laboratories and 340 metrologists in industry, Federal agencies, or foreign laboratories on the NIST Weights and Measures Division metrology mailing list. The NIST Weights and Measures Division trains from 10 to 20 State metrologists each year in the Basic Metrology Seminar for States (where the first week covers mass), and another 10 to 30 industry, Federal, and/or foreign metrologists in Basic Mass for Industry (hands-on mass calibration) at NIST. Every scheduled class is filled, and there is often a waiting list to get into the classes.

Within the last two years balance and scale service companies and companies with in-house weighing processes that need to ensure intermediate verification of their mass standards between calibrations, and that need to evaluate measurement uncertainties for the process of calibrating balances and scales, have made an increasing number of requests for training. During this period of time, approximately half of the participants in the Basic Mass for Industry course represented this new segment of the weighing community. These additional requests resulted in even larger waiting lists for each class.

Relationship to the System
The primary target audience (State laboratory metrologists) for the Basic Mass Metrology CD-ROM provides measurement and calibration support for the entire weights and measures enforcement system in the United States. About 340,000 calibrations per year for 19,400 customers are provided in the 55 laboratories that are a part of the State Laboratory Program system. No estimate of the total calibrations provided by private industry participants who have completed this training has been obtained. Key staff of all U.S. mass manufacturers have also completed this training.

Technology
The metrology community is comprised of people with extensive interests and capabilities in using computers as an integral part of providing calibration services. Metrologists represent a technologically advanced group, especially within the weights and measures community, whether communicating via e-mail, obtaining resources and information via the Internet, collaborating and sharing resources with multipoint network conferences, creating and sharing spreadsheets and other software for calculating calibration results, collaborating in the development of standards requirements, and automating measurement processes by interfacing computers with laboratory instruments. Today, nearly all laboratories have access to computer tools as a part of their everyday operations.

While most laboratories have computers available, and the vast majority have access to e-mail and Internet services, high bandwidths are not universally available, and a national network among weights and measures constituents is not maintained. As a result of the current technical limitations, our plan is to begin the process of delivering training electronically through the development of an interactive, multimedia CD-ROM. This product is intended to serve as a beta test for the conversion of all WMD training methods and materials to electronic format.

Purpose and Objectives of the CD-ROM Project
The purpose of this project is to develop a 12-hour (approximately), multimedia CD-ROM-delivered training course on making basic mass measurements. While it was anticipated that the CD-ROM course would be about 12 hours long, it is now closer to 16 hours (a result of including more technical content).

This CD is intended to provide:
- an initial introduction to mass metrology for new staff;
- supplemental training for staff who recently attended a basic mass metrology seminar and want to review training material prior to working in the laboratory; and/or
- updated refresher training for laboratory staff who completed their basic metrology training so long ago that updated training would be useful to ensure measurement uniformity.

The primary objectives to be achieved through the implementation of this CD-ROM-based training for mass metrology are listed below:
- ensure that new laboratory staff in State weights and measures laboratories are more prepared to provide basic measurements to support legal metrology when NIST training is not immediately available;

- ensure that new laboratory staff in State weights and measures laboratories have uniform resources available during their initial training in the laboratory so that they can attend seminars at NIST without major insecurity and fears of failure;
- give States a means to screen potential metrologists and participants by requiring successful completion of the CD training prior to costly attendance at a NIST seminar;
- provide opportunities for industry or foreign metrologists to obtain an introduction to basic mass metrology when they are either unable to attend hands-on training at NIST or language barriers make the learning process difficult;
- make it possible for recently trained metrologists to review specific material prior to applying new procedures in their laboratory. So much information is covered in our one-week basic mass seminar that ensuring a thorough understanding of basic mass calibration principles is critical;
- enable staff who have not received training in the most recent five to ten years to learn the latest procedures in mass metrology and to identify and correct poor measurement habits they may have developed in the laboratory. Measurement errors are often observed during interlaboratory measurement comparisons. A refresher course or continuing education delivered via CD-ROM may improve the technical competence of metrologists; and
- provide an opportunity for documentation of metrology training as required by ISO 9000, ISO 17025 (formerly ISO Guide 25).

NIST "Basic Mass Seminar" Overview

The "Basic Seminar" taught by the WMD at NIST has been provided as a two-week course to metrologists working in State weights and measures laboratories since the 1960's. The course covers basic concepts needed for all metrology disciplines and specifically covers calibration procedures for mass, length, and volume. In 1994, based on requests, the WMD began offering to metrologists from industry laboratories the first week of this course, which covers mass metrology. The added course is the "Basic Mass Seminar for Industry." Each course is offered two or three times each year on a break-even, cost-recovery basis. As stated earlier, courses fill quickly and there is often a waiting list. A course description follows:

Course Description for Basic Seminar for States

> "This course is limited to participation by State metrologists on a first-come, first-served basis since it is a requirement for legal metrology Recognition. If room is available, other metrologists are welcome.
>
> The Basic Metrology Seminar is a 2-week, "hands-on" seminar. It incorporates approximately 50 percent classroom work and 50 percent laboratory work in which the trainee performs measurements by applying procedures and equations discussed in the classroom. The seminar focuses on the understanding and application of the procedures, the equations, and calculations involved, including the calculation of standard deviations and uncertainties, error analysis, the operation of the laboratory equipment, and the review of publications, standards, specifications, and tolerances relevant to the measurements likely to be performed by the metrologist. The first week is dedicated to mass measurement, while the second week is split between length and volume

measurements. The entire seminar incorporates statistical analysis, process measurement assurance methods, and uncertainty analyses.

As a result of successfully completing the Basic seminar, a metrologist should be able to perform basic level calibrations (tolerance testing) and calibration of mass (without air buoyancy corrections), length, and volume standards. Air buoyancy is usually not covered due to the lack of time and the extensiveness and complexity of the subject. Basic Laboratory Auditing Program (LAP) problems are assigned at the end of the course for completion in the student's laboratory. Acceptable completion of the LAP problems is required for WMD laboratory Recognition at the basic calibration levels.

The suggested minimum requirements for a metrologist attending the Basic seminar are a good knowledge of algebra, basic knowledge of physics and statistics, and some laboratory experience. NBS Handbook 145 is used as the main text in the Basic and Intermediate courses and includes most procedures currently in use in the State weights and measures laboratories.

A NOTEBOOK PC MAY NOT BE USED DURING THE BASIC SEMINAR!!! A scientific calculator and familiarity with its operation are required."

Application Focus

The hands-on seminar at NIST is very *application* focused. The primary objective enables students to gain enough proficiency and competence to make measurements in their laboratories at a level that allows them to present good calibration results to their clients. The main focus is to ensure that metrologists make good measurements rather than simply transfer information.

By looking at the list of topics covered in the hands-on course or on the CD-ROM, it might seem that courses at NIST should be taught at a more complex or advanced level. However, it is essential to cover each topic to ensure that metrologists have a solid foundation to build on in subsequent courses and be able to apply the concepts in their laboratories.

The concern for building a solid foundation is related to a requirement in the U.S. weights and measures system for uniformity in measurements used in commerce. Because a Federal weights and measures regulation in the United States is generally a state and local function (where each of the 750 jurisdictions adopts all or a portion of what NIST publishes), much of the uniformity in the legal measurement system is acquired through the use of NIST-published procedures and the correct implementation of those procedures as achieved through the WMD metrology training courses. The effectiveness of this process can be easily measured in the laboratory arena through review of the assigned LAP problems and round robin data that are collected from the State laboratories each year. When students skip courses, and fail to meet the prerequisites for the course (at the next level) in which they chose to participate, progress is much slower than it would be otherwise. If instructors have to spend excessive amounts of time trying to build a foundation for students who haven't attended the prerequisite courses, it disturbs the normal flow of the course.

Each Basic course begins with students performing basic mathematics exercises using (required) a scientific calculator. While skills in "basic mathematics" might be assumed as fundamental, or that students are able to use computers in this era, there is a wide range of students and capabilities, who attend courses at NIST. On one hand, some have advanced degrees, have been working metrologists for 20-plus years, have laboratories that are completely automated, remember mathematical orders of operations or dimensional analysis concepts, know how to handle scientific conversions and know the SI unit prefixes (e.g., kilo for 10^3), and regularly double-check calculations with a scientific calculator. However, the other extreme is also frequently observed. Therefore, WMD metrology instructors review the basic mathematical concepts at the beginning of each class and gain an understanding of which students need extra help when performing calculations during the course. Since so much of the class is hands-on, and the goal is to ensure successful application, a review of basic mathematics proves to be very beneficial. This basic mathematics topic is also covered in detail on the CD-ROM course and includes tips for using a scientific calculator.

The Intermediate course builds on the concepts and procedures taught at the basic level. Such topics as Statistics, Measurement Assurance, and Uncertainty Analysis are presented at a very simple, fundamental or nuts and bolts level in the Basic classes; subsequent seminars build on these topics. Thus, in the later seminars the students at approximately the same level of understanding and the material can be covered much more effectively in a standardized, uniform way than was possible during the basic seminar.

Instructional Theory

An Internet site (http://www.indiana.edu/~idtheory/home.html) describes Instructional theory as "a variety of methods of instruction (different ways of facilitating human learning and development) and [explains] when to use--and not use--each of those methods. It is about how to help people learn better."

The NIST metrology classroom course design incorporates a number of instructional methods. For each exercise the students are given reading assignments in advance, followed by a lecture presenting the topic, with a subsequent demonstration of the procedure and calculations. Students then make measurements and calculations, and the results are reviewed and discussed. Whether a student is an auditory learner, visual learner, or tactile (hands-on) learner, each can profit from a procedure that uses multiple learning approaches. This technique provides a good balance since feedback may indicate the need for more hands-on time, more demonstrations, or perhaps even more homework.

Metrology Thinking

In addition to building a solid foundation and focusing on successful application of the concepts and procedures via multiple learning opportunities, a significant portion of time is devoted to helping students learn to "think like a metrologist". Evaluation of data is a *critical* step in providing good measurement results to laboratory clients. A metrologist *must* be able to look at measurement results and determine if they are good before providing them to the client. Any number of mistakes can occur at each step in a measurement process. Questions enable the students to identify what types of mistakes occur and when they are most likely to occur during each procedure. New metrologists often assume that the software in their laboratories is "good" or that their calculations from the calculator screen are "right" simply because they display ten

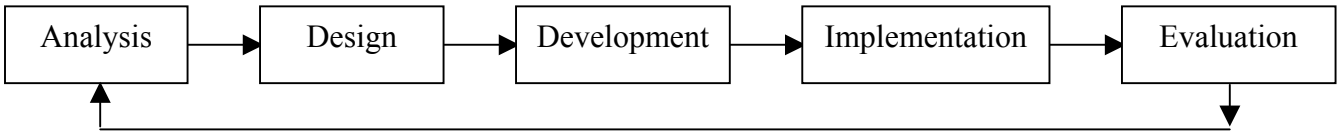
digits! The training focuses on helping metrologists determine which digits are meaningful. One extra feature of teaching metrologists in an application-focused environment is that they all need to apply the concepts once they return to the laboratory, so they have a vested interest in classroom success.

Note: See Appendix A for the course outline for the hands-on course at NIST and see Appendix B for the detailed outline for the CD-ROM course.

Development Process, Phases & Lessons Learned

There are many methods (perhaps hundreds) of instructional design used or discussed in academia. However, few metrologists have a background in educational methods or instructional design unless they happen to have interest/experience in multiple professions or are in academia and providing courses related to metrology. The merits or approaches of various methods are not presented here, but the process can be likened to the familiar statistical process control (SPC) model: Plan, Do, Check, Act. And, like any good metrology term or approach, it comes with its own acronym: ADDIE.

ADDIE stands for Analysis, Design, Development, Implementation, and Evaluation. These self-explanatory labels for the learning life cycle can be used for each lesson, each course, or an entire training program. It is a comfortable approach for metrologists to follow because it is intuitive, easy, iterative, and similar to models already in use in metrology. It is also one of the first instructional design models, so additional information is easily found on the Internet, in training and educational resources, and in academic courses.



These phases, as used in this section, describe the development process used, each of the steps in the process, and the lessons learned so far.

I. Analysis

Background Need
The background analysis and need for this project was provided in the first section in this paper. The audience, their technical capabilities and resources, and needs for training were analyzed, along with the number of requests received for training that NIST is unable to meet. The Analysis provided (and still does) a good measure of the system-level need for mass metrology training. Early in the analysis phase, several types of technology-based training (e-learning) were analyzed, and the best approach for the target audience was determined at that time. Primary consideration focused on on-line Internet-based options and CD-ROMs. Based on bandwidth considerations and the desire for complex interactions and availability of the course during non-working hours, a CD-ROM approach was chosen as the best option for the audience. However, to provide maximum flexibility and modularity for the material, the original Request

for Proposals (RFP) required that the design approach facilitate easy conversion of the material to on-line learning formats.

Background Resources
Conferences and seminars are widely available in the field of e-learning. On-line resources abound as well. Gaining background information on a "new" set of abbreviations and acronyms and learning a new discipline-specific language are critical in starting a project of this sort. In fact, it is essential to understanding the resource material available in this subject. Examples:

- CBT: computer-based training
- TBT: technology-based training
- ISD: instructional systems design(er)
- ADDIE: instructional design model
- ASTD: American Society for Training and Development
- SALT: Society for Applied Learning Technologies

In addition to obtaining background information on this discipline, several service providers gave presentations at NIST about their companies and capabilities, showing us samples of typical products and offering their ideas and insights. Providers who were active in ASTD and who were also on a special government-contracting schedule for developing products with the type and level of interactivity needed in the finished product were targeted. Several staff participated in the vendor meetings and gained ideas for other office projects.

Note: In accordance with Federal procurement regulations, all interactions with service providers occurred before the Purchase Request and the final Request for Proposal were prepared.

> *Lessons Learned:*
> Overall, the activities that helped gain an understanding of the training needs, the e-learning discipline, and the types of products, resources, and technical approaches that are available were positive. Interviewing potential providers was an invaluable part of the analysis phase because expert opinions and insight were obtained before the procurement process was completed.

Request for Proposal
Working within the government procurement system can be quite a challenge. At NIST, an Acquisitions and Assistance Division (AAD) assists with developing statements of work, provides contracting vehicle information [e.g., GSA is the most commonly known, but MOBIS (Management, Organizational, and Business Improvement Services, SIN 874-4 Training Services) was used for this project], ensures government contracting requirements and regulations are met, etc.. The AAD office maintains a web site with checklists, forms, and sample outlines for statements of work that can be used as models when developing a request for quotes or a request for proposals. It is also possible to contact procurement staff before completing any paperwork to get help in determining exactly what steps and forms are needed for unique projects, for determining the best contracting approach, for developing a clear and complete statement of work (SOW), and for assistance in complying with the government-

mandated 508-compliancy (i.e., accessibility regulations) requirements for IT products and services.

In addition to the procurement tools and references provided by the AAD staff and web site, some instructional design and e-learning resources were researched to find sample Requests for Proposals (RFPs) specifically tailored to the development of CTB/TBT materials. These samples ensured that unique aspects of purchasing e-learning services were addressed in the RFP.

Evaluating the technical content of each vendor's proposal was an important step in selecting a contractor. Because the technical criteria were established with the request, we were able to evaluate the technical content and not simply go with a low bid. Once the paperwork was completed and the request was released, NIST received three complete proposals with significant differences in technical approaches and subsequent costs. Based on the criteria provided in the original RFP, a technical evaluation of each proposal was completed, ,. a final decision was made, and the contract was processed.

> Lessons Learned: It is essential to work with procurement staff from the beginning of any project, and even more so when it entails the complexity or uniqueness (for WMD) of an e-learning project. We profited from the use of sample SOWs and RFPs as models and shared completed resources with other members in WMD for the development of related products in other technical areas (e.g., WMD is developing a CD-ROM on Audit Trails used for controlling software changes in commercial measurement devices). It is important to anticipate 508-compliancy issues with any type of project and to be able to provide instructional alternatives. For example, because a hands-on course is available, a student has the option to attend the course at NIST if the CD-ROM course proves to be a learning barrier.

Deficiency in the RFP

The biggest hurdle that WMD (and the contractor) encountered on this project, which should have been more thoroughly addressed in the RFP, was related to the thorough NIST technical and editorial review process which had to be applied to a multi-faceted training course. Special approval was sought to allow approval by the readers and sponsor as each module was completed. All NIST publications are required to undergo extensive review in order to and gain approval for publication from the Washington Editorial Review Board (WERB) (Gaithersburg group). Technical and editorial reviews are completed at the Division level, outside the Division, and from the operating unit (OU) WERB sponsor prior to being approved for publication.

Because of the number of modules (15, plus subtopics) and the complexity of three key developmental phases (Word draft, Access/Storyboard Database with graphic and programming instructions, and Programmed material), the time and resources required for NIST, as well as for the contractor, were seriously underestimated in this aspect of the project. Technical staff outside the Weights and Measures Division reviewed each of the 15 modules. Based on the specific topic, different experts reviewed each of the modules. For example, the staff in the NIST Statistical Engineering Division reviewed the mathematics and statistics sections, but the NIST

Mass and Force Group reviewed air buoyancy corrections. In some cases, such as the module on Uncertainties, both the Statistical Engineering Division and the Mass and Force Group reviewed the material.

During early content development, all reviews were performed after the final phase (programming). However, when the reviews were done at this stage, many needed technical and editorial changes required complete reprogramming of each screen resulting in significantly increased costs for the contractor. The review process was revised to complete all technical and editorial reviews prior to the programming phase. Unfortunately, there were also drawbacks to this approach because reviewers were unable to review the interactivity, the on-screen presentation, and understand how the graphics worked with the text to communicate complex concepts. Luckily, enough programmed modules were shared with reviewers prior to the process change that it was possible to "imagine what the final screen would look like" while looking at the paper version. This early exposure to the programmed material was vital for later review of textual material.

> Lessons Learned: The technical and editorial review process was enhanced significantly in the subsequent Audit Trail RFP project and in the contractor's management plan and schedule for the project. That is, the next project benefited from understanding the process revisions and incorporated detailed review requirements in the next SOW/RFP.

*Schedule/Plan the Projec*t

The first deliverable in the CD-ROM project was a Management Plan addressing the approach and schedule for the entire project. Several meetings were held with the contractor to review and provide input to the draft Management Plan. The RFP specified that the plan include a schedule that would be developed and managed with standard project-management software. In addition, regular reports were to be submitted to track progress, deliverable status, and critical problems as they arose.

During the course of the project, management plan, design, and content files were generally transferred back and forth between NIST and the contractor's project manager as e-mail attachments. Larger databases or graphic files were stored on various media and sent back and forth by overnight carriers or couriers. Although the contractor's office is in the Washington D.C. area, relatively little time was spent in meetings and formal reviews.

> Lessons Learned: The use of standard software tools was a good first step for the project. Unfortunately, with project delays due to writing/review problems, the project quickly fell off schedule, and project reporting essentially indicated that "everything is late." The two major sources of project delays were 1) the contractor's lack of an adequate understanding of the WERB review process and 2) the planned content development approach using instructional designers failed. (This will be discussed in the next section.)
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> Setting a realistic schedule based on the WERB review process was subsequently placed in follow-on contracts and is reportedly working well. Scheduling content development is discussed further in the "Develop" section.

II. Design

Develop Content – Planning

During the design phase, a two-part document, Learning Analysis Report and Media Design Guide (LAR/MDG), was prepared. This document was the second project deliverable. One part of the document, containing all of the media design requirements for the entire project, This portion of the document provided the baseline for all questions regarding style and formatting of on-screen materials, even including colors and font styles/sizes. All of the NIST media design guidelines were provided to the contractor for review and for summarizing in the plan (WERB requirements for grammar, style and presentation of text, punctuation, and formatting, Internet-page style guides, guidelines for correctly presenting measurement results, SI units, etc.). The contractor's CD-ROM development process and media approaches were also evaluated and summarized in the guide along with the final project style guides. These included details of the functional elements, the interface, screen layout, and the use of various multimedia components (video, narration, graphics, etc.).

Developing the Learning Analysis Report (LAR) portion of the document provided a good learning exercise for NIST staff. It required metrologists (with some education in training) to work with the contractor's project managers and instructional designers (trained in the tools and methodologies for enabling effective learning) to detail the course outline, identify specific modules and topics, and, most critically, detailed learning objectives. Ways to measure whether the objectives were met for each topic were identified at this time. The sample outline from LAR Statistics topic in Module 1, Lesson 2 (M2L1) is provided in Appendix D. Note that it includes three topics. The final form of this module includes these same three topics. However, sometimes during the content development phase, the outline did not quite match what was determined to be the best approach for presenting complex technical material in a CD-ROM format. While the LAR formed the baseline for the entire course, occasional deviations occurred from the outline to support the best instructional methods.

Also during this phase, the contractor's instructional designers attended and participated in two hands-on classroom courses, took notes, made hands-on measurements in the laboratory, video-taped portions of the lectures, and collected the reference materials used in the course. The original project plan and schedule was based on instructional designers writing the entire course content, followed by NIST reviewing and providing comments.

> Lessons Learned: The Media Design Guide is an exceptional approach for ensuring consistency in style and formatting in a large project. This was especially important for the contractor since several of their programmers and graphic artists worked on multiple projects during the development phases; thus they had the MDG as a reference document for review. It also provided a reference document for quality assurance reviews.
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> Developing the Learning Analysis Report was an excellent learning exercise for NIST staff to develop skills at focusing on presenting learning objectives to enable specific outcomes, rather than just "informing" the student. Because the instructional approach already focuses on application, this was an experience to be applied to all of the WMD

hands-on courses and training. Finding ways to increase the level of interactivity in training efforts should improve the level of consistent implementation in the laboratory.

Prototyping

The third project deliverable was a CD-ROM "rapid prototype" and was closely related to finalizing the Media Design Guide. A rapid prototype was included in the RFP to ensure very early in the project that the style, format, approach, and content presentation would meet the requirements and that the interactivity was at the desired level. NIST obtained valuable feedback from working metrologists who evaluated the prototype. As mentioned earlier, a primary goal for designing the CD-ROM course was to make it as interactive, hands-on, and application-focused as possible. It is quite a challenge to translate a classroom course that is over 50 percent hands-on in the laboratory to be nearly as interactive on a computer!

Lessons Learned: It is a good idea to include a rapid prototype in the RFP and be sure to take advantage of this stage to provide as much critical, detailed feedback as possible to ensure that the final product will meet expectations.

III. Development

The original steps used to develop content were these:

1. Contractor ISD prepares draft storyboard,
2. NIST (WMD) reviews and provides Feedback,
3. Contractor programs the lesson and posts on an Internet site for review,
4. NIST technical staff and WERB sponsor review programmed material, and
5. Programming corrections made.

Due to two major problems on the project (which will be covered shortly) and project costs for the contractor, the steps were revised as follows:

1. NIST (WMD) prepares draft Word document; converted to storyboard database by contractor,
2. NIST (WMD) finishes content in storyboard,
3. NIST technical staff and WERB sponsor review material,
4. Contractor programs the lesson and posts on an Internet site for review,
5. NIST (WMD) reviews programmed lesson for accuracy against the storyboard, and
6. Contractor programs changes and NIST reviews again.

The two major problems during the development phase were: 1) contractor instructional system designers were not able to translate complex technical content in a manner that satisfied NIST subject matter experts, and 2) the order of the development, review and programming steps significantly added costs for the contractor due to extensive NIST technical and editorial reviews.

Lessons Learned: It was anticipated that the ISDs would be able to write the content, which would be scheduled and staffed accordingly, but the level of complexity and detail needed to translate metrology concepts and topics into CBT material made it impossible to accomplish by people who were not subject matter experts. The contractor's project

manager, who also has a background in engineering, was able to develop material near the level expected for the course. However, the contractor dedicated three ISDs and a project manager to work on content in the early stages of the project. Non-subject matter experts were unable to convert the highly technical course materials to CBT with the preciseness needed for NIST publications. This was a lesson learned for the contractor.

NIST staff (WMD), who originally anticipated that the ISDs would be writing content, had to reallocate work to focus on writing content. This was an unexpected, added expense for NIST and significantly delayed the project. While this problem was anticipated, the contractor initially assured WMD that the ISDs could write the content if given the resources. However, NIST staff who were highly knowledgeable in the subject matter had to undertake content writing.

After negotiations with the contractor, the development steps were revised about one-third of the way into the project. Funds were added to the contract to cover additional expenses incurred by the contractor due to extensive reviews and programming in multiple phases. The revised steps ensured that all NIST reviews were completed prior to beginning any programming. Even with modifications, significant reprogramming was required after each review due to the extensive number of measurement units, symbols, superscripts, subscripts, and detailed formatting requirements used in the project and the high quality requirements at NIST.

Develop Content – Writing

Each final screen in the CD-ROM course is represented by one or more "storyboards". A storyboard consists of all content and instructions needed to program each screen. An Access storyboard database includes embedded Word files, Equation Editor files, Excel files, graphic file names and narration file names. Initial storyboard databases were provided to NIST in a "locked" form so that comments could be entered via an integrated comment form or in a separate Word document. Based on the revised content development phases, the draft material was developed in a Word document and included suggestions for programmers, graphic artists, and feedback on activities, giving enough detail to complete the Access storyboard database. The draft Word documents were provided to the contractor for review, feedback, and conversion to the Access database. Each final database, which contains an entire module with all topics and materials except for the graphic and narration files, was returned to NIST for completion and final review. Graphic media may include created graphic files (handled by the contractor) or photographs (provided by NIST).

As noted earlier, NIST originally anticipated (based on assurances from the contractor) that the ISDs could write content, but the translation of highly technical content developed by ISDs was not satisfactory for NIST. As a result, NIST time and staffing were required to write instructional content. The time and dedicated resources could not be solely dedicated to this project; therefore, significant delays in the schedule occurred, and the original management plan and schedule were unattainable. The original schedule showed a final draft product in six months. The time spent on the project to date is two and one-half years.

One item that NIST created to assist in development and review was a graphic flow chart of the screens to enable imagining, based on a stack of paper, the final interactive screens that include tips, hotlinks, and rollover content interaction. Flow charts were created in an outline form either on a whiteboard or in Excel.

> Lessons Learned: Complex metrology concepts are not easily transferred to instructional designers for content development unless they have extensive scientific/engineering background and have attended specific metrology training. Content development must be planned into the project schedule. Dedicated staffing is highly recommended if possible, and is essential if short deadlines are desired.
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> NIST experience with Access, Excel, Word, Equation Editor, graphics and embedded files, and objects in Access was essential. NIST obtained "unlocked" version of storyboard databases for direct editing and technical review. Software control is also necessary to ensure that office computer upgrades were not made during the development stages (e.g., the database uses Access from Office 97).

Develop Content/Writing – Video

To increase the amount of interactivity, video was chosen to demonstrate a few key procedures. The total video content was limited to five minutes due to costs and size of video files for a CD-ROM. The use of animation and photos in series to demonstrate procedures was also considered to be more effective than long-running videos, which are less interactive. To watch a balance stabilize for 30 seconds each time a measurement was made would be boring.

The planning and taping of the video sections was fun! The script (which came directly out of the storyboard) was developed, and a dry run (practice session) was held with our *actors* (NIST staff) and a WMD video camera. The video was shown to the professional videographers when they came the next day and they were able to very quickly assess what they needed to shoot, what angles and perspectives (far, medium, close-up shots) they would need, and what the timing might be. The entire video was shot in one day without need for retakes.

After narration was obtained from the narrator, NIST and the contractor's project manager met at the subcontractor's editing facility to edit and synchronize the video segments and narration most accurately. It was essential for the NIST staff to participate in the editing to make sure that the right views were being shown and that inappropriate shots were excluded (e.g., when a balance wasn't showing a good "release" the clip was deleted in the final video).

> Lessons Learned: Having a dry run was a good idea, both for NIST staff and for the videographers. It saved a significant amount of time overall and resulted in a good video product that was very satisfactory. The subject matter experts must participate in the editing and synchronization phase.

Develop Content/Writing – Narration

The contractor originally planned to use in-house, trained voice talent. The NIST staff was not satisfied with the voice/audio quality when they heard samples of the narration and chose another approach (which added minimal costs). The NIST Public and Business Affairs (PBA) office has

staff who regularly work with video production, graphic design, and multimedia materials for marketing and general use. For example, they coordinated the "NIST at 100" video and annually coordinate the Baldridge Quality Program "Quest for Excellence" CDs. The PBA office lent WMD a CD to review samples of narration/reading from local voice talents (both male and female, with a wide variety of voices). Several staff listened to the samples and picked out their favorite top five voices. Listening to the top voices narrowed the list, and a final list of three (one for Spanish language and two for English, depending on availability) was selected. Detailed instructions were needed for the narrator and recording studio; and the PBA office managed the narration process and provided us with the final narration files. The final files were submitted to the contractor for programming after reviewing several samples.

> Lessons Learned: It is critical to hear and agree to the contractor's voice talent. Be sure that their plans for narration meet your expectations and, of course, budget accordingly. The alternative approach and narration results were very satisfactory.

Develop Content/Writing – Graphics
The amount of time to develop graphics (review sample graphics, create charts, and take photographs) was another underestimated area. . Several thousand photographs (over 7 000 to date) were taken to select those that would communicate a concept or procedure most effectively. It was initially anticipated that the contractor would visit the NIST laboratory with a list of photos to be taken, assistance would be given with staging, and the best photographs would be selected. However, more photographs were needed than could reasonably be taken in a short period of time with a contractor on site, and WMD wanted more control over the final quality and selection of the photographs. The contractor provided instructions to NIST and NIST assumed the task of taking and selecting photos for each lesson. The number of photographs that were taken is large enough to be usable for a variety of training projects.

WMD also negotiated the level of detail and quality that was needed on graphics created by the contractor. For example, the opening background screens and text background contains a watermarked "graph paper" look and feel. The original prototype had divisions that looked like "inch divisions," but it was revised to show decimal units and represent a more "metric" feel. When statistics graphs were prepared, some of the early drafts of a *normal distribution* included curves that touched the axis. This was unacceptable. When x's represented data points on a chart and a number like 14.7 looked more like 14.9 on the graph, corrections had to be made. Most graphic artists are unaccustomed to the level of technical detail that NIST demands. Because the contractor's project manager has an engineering background and participated in one of the hands-on courses, she began to do a quality check on all graphics before NIST received them for review.

> Lessons Learned: The amount of time needed to obtain a good collection of photographs was underestimated. The contractor also underestimated the level of detail to which graphics would be scrutinized by NIST and the amount of time that would be required.

Review
When the technical and editorial reviews were completed after programming (in the original development stages), it required many programming iterations, which significantly increased the

costs for the contractor. A small increase in the budget to cover some of these costs was negotiated, and WMD completely revised the writing and reviewing approach as noted earlier. However, the level of quality assurance needed on this project continued to be extensive, even when using the media design guide as a baseline and when final reviewed/approved storyboards were provided to the contractor for programming. An ability to handle metrology-related equations and formatting is not a typical skill for a graphic programmer. Extensive use of examples, numbers, equations with Greek symbols, superscripts, subscripts, and other mathematical variables required extremely close quality assurance reviews and comparison between what appeared on the programmed screen and the final, approved storyboard.

Another aspect of the review that was hard to anticipate was how the mix of text, equations, and graphics would interact on the final screen and be communicated most effectively. When the final review was made on the programmed material (early in the project), it was much easier to consider the interplay of the media and provide technical and editorial comments. Later, when reviewing paper versions, it became much harder to imagine the final screen view and interactivity. The reviewing abilities of the WMD staff improved over the course of the project, and the review became less of a concern as the writers and reviewers became more skilled at imagining the final product.

> Lessons Learned: Neither the contractor nor NIST anticipated the time required for editorial and technical reviews or the availability of staff (who were usually in the midst of other full-time responsibilities). While WMD staff made changes in the process and review methods, time and staffing resources continued to plague both NIST and the contractor during the entire project. Again, sample exposure to programmed screens early on made life easier for imagining the screen from text.

Translation to Spanish

When the project was about 80 percent completed, WMD obtained funding approval to translate the entire project and provide a version of the Basic Mass Metrology course in Spanish. WMD receives numerous requests to provide training in Spanish. While one of WMD's contract trainers is bilingual (English/Spanish), it is difficult to get enough students in one class to make it cost-effective to offer the course in Spanish. Travel costs are also a major problem for students, which prevent many interested students from attending the hands-on course.

A number of contacts for experienced translators (experienced with metrology/technical content) were provided to the Procurement Office, but translation services (above a cost level for which a credit card could be used) are covered under a GSA contract. Once the contract was written for the translation provider, WMD held a meeting to become familiar with the translation contractor's usual translation/review process and to negotiate modifications for the process based on reprogramming needs. The programming contractor did not have bilingual staff available to ensure correct placement and programming. Therefore, screen captures of the final content were inserted graphically in Word and the translated material was entered for each screen consecutively. The quality assurance checks are likely be even more of a challenge than with the English version.

The entire project, from procurement to programming review is now being repeated, with the added complexity of translating the material and having it reviewed by Spanish-speaking (bilingual preferred) technical experts. WMD identified metrology experts in Columbia, Mexico, Uruguay and Puerto Rico who have agreed to participate in the review of translated content. They are all mass metrology experts, and it is hoped that the final product will be useful for them and their laboratory clients.

> Lessons Learned: As the translation project is begun, the lessons learned will be implemented. But, while WMD provided translation contacts for sole-source or competitive quoting, the procurement staff decided to use GSA contracting. Had this been known in advance, WMD would have brought in potential vendors to get a better understanding of translation provider processes prior to writing the statement of work. Also, now two and one-half years into the project, the procurement requirements and regulations have changed. New requirements include the following: 508-compliancy for the contract, a quality assurance plan for the vendor, and a legal review of both the contract and request for quote. So, while WMD planned and hoped to learn from our previous lessons, change in the system was inevitable.

Note: See the summarized phases and lessons learned in table format in Appendix C.

IV. Implementation

The CD-ROM has not been distributed as of the writing of this paper. The planned distribution is to provide first-run copies to all students who attended the Basic Mass Metrology seminars. Originally 500 copies were estimated for duplication/replication. We anticipate that additional copies will be purchased. After the original contract was in place, WMD found out that it would not be able to recover the costs for development of the course, and WMD would have to give away the final CD. Consequently, WMD anticipates a fairly large demand for the final product based on the number of modules that have carry-over applications for other areas of metrology (especially statistics, measurement assurance, uncertainties).

The CD-ROM was not intended as a replacement for the hands-on course: obviously some people will not learn well and/or will be unable to apply these concepts well using technology-based learning tools so that the demand for the hands-on course will not likely drop significantly. WMD also plans to give copies of the CD to new students for follow-up review.

WMD will give presentations on the development process and provide copies of the CD during conference presentations, demonstrations, and laboratory tours at NIST. In addition, WMD anticipates requests to provide the CD for use as “give-aways” at conferences where NIST exhibits.

V. Evaluation

Literature on the topic of e-learning or technology-based training also makes many references to evaluating training and evaluating the implementation of new types of training. Metrologists

excel at measuring, but to date there is no plan in place to "measure" the effectiveness of the course. It is hoped that the features designed into the CD-ROM course, will provide feedback:

1. A request for comment, feedback, and effectiveness was included in Module 0 (navigation).
2. A notepad feature was included in the course so the student can record additional comments and questions and send the file as an e-mail attachment to NIST for follow up.

WMD will be able to measure some level of success for the course based on:

1. numbers of CDs requested/duplicated;
2. numbers of completed feedback/notepad files;
3. number of questions/requests for additional information;
4. increased numbers of students requesting our Intermediate or Advanced course;
5. anecdotal stories and case studies of use and impact; and
6. improved results on round robins (though hard to relate to completion of the CD-ROM training).

The financial impact will be evaluated from several perspectives:

1. Have users saved money from not traveling to NIST?
2. Has NIST saved money from not holding a hands-on course? (Since the metrology courses are designed for cost-recovery and breaking even, a significant savings is not anticipated.)
3. Will the courses and course material have greater impact through wider distribution than what has been achieved with only the hands-on course?

A formal plan for gathering data and feedback from the initial distribution list needs to be developed. It will be much harder to gather data when the CD-ROM is distributed at conferences and exhibits if/where names and addresses are not routinely collected. The Evaluation phase is likely to be an area where additional study and assistance to measure and evaluate the effectiveness and leveraging of government resources used on this project will be needed.

Summary

The development of this course has been challenging in many ways. It has been a useful learning experience which has allowed WMD to gain a better understanding of instructional design methods, integrate instructional design and metrology concepts and disciplines, and gain experience managing a project (over $500 K) of this scope/scale. The WMD metrology staff have also become much more skilled at reviewing on-screen materials for accuracy and style.

WMD has tracked the lessons learned from the beginning of the project and were immediately able to share them with others as the office initiated a CD-ROM course development for Audit Trails. The lessons learned have also helped as the process of translating the final mass metrology content from English to Spanish is begun.

As e-learning is implemented in other areas of metrology, WMD certainly recommends learning from others' mistakes, using a modular approach for presentation and reusability of technical content, and integrating instructional design concepts and learning styles and methods into metrology instruction.

The content and quality of the nearly-finished CD-ROM course is exciting. A significant portion of the individual instruction and guidance that is provided in the hands-on course, but which has never been documented in a meaningful way, is now presented in the CD-ROM course. For many years we received requests for follow-up resources to the hands-on course, and now a new product is available to meet this need.

Credits & Dedication

Like any good movie or multimedia production, this one could not come to fruition without the full cast. My thanks to all – none of this could have been completed without the enthusiastic and supportive participation of the following colleagues and contractors.

NIST Staff

- Weights and Measures Division: Henry Oppermann (original proposal, encouragement, time, support), Joan Koenig (original RFP development, contractor evaluations) Val Miller (extensive development and review assistance), José Torres (development and review assistance)
- Technology Services: Rich Kayser (funding support)
- Standards Services Division: Walter Leight (WERB sponsor and reviewer of all sections), Doug Faison, Ken Butcher, Carroll Brickenkamp, (technical reviews of key sections)
- Manufacturing Engineering Laboratory: Mass & Force Group – Zeina Jabbour, Jerry Keller (technical reviews of key sections), Jerry Keller (video)
- Information Technology Laboratory: Statistical Engineering Division– Raghu Kacker, Jim Filliben, Nell Sedransk, Ivalisse Avila, (support/technical reviews of key sections)
- Administration: Public & Business Affairs – Ron Meininger; Procurement - Beverly Conward, Randy Schroyer, Joseph Widdup, James Knight, Alba Sanchez

Photographed Laboratories & Metrologists

- NIST (WMD), NIST (Mass & Force Group), Arizona Department of Weights and Measures, Tennessee Department of Agriculture, Maryland Department of Agriculture, Pennsylvania General Services Administration, INSCO Metrology, Miami
- Kelley Larson (AZ), Joseph Hyla (MD), Zenon Waclawiw (MD), Tom Hale (PA), Ed Carpenter (PA), Pete Millvan (PA), Tom Smith (TN), Ivette Escobar (INSCO, Miami), Dimaries Nieves (INSCO, PR), José Torres (PR), Val Miller (NIST), Diane Lee (NIST), Danny Newcombe (ME), Jerry Keller (NIST)

Contractors

- Project: C^2 Technologies (www.c2mm.com) - Susan Dass (project manager, primary contact)
- Subcontractor: Beach Associates – Jan Dearth (primary contact for video)
- JTI Systems: Rick Rios, John Clark, Jerry Everhart (Measurement Assurance Module)
- Narration: Kirk Penberthy
- Translation: All-World Language Consultants (www.alcinc.com) - Melanie Wexler (primary contact)

Translation Reviewers

- Mexico (CENAM): Luis Omar Becerra, Jorge Nava
- Columbia (SIC): Jorge Garcia Benavides
- Uruguay (LATU): Luis Mussio
- Puerto Rico (NIST Contractor): Jose Torres

Appendix A – NIST Course Outline

Agenda for Basic Seminar for States - Sample

Monday		Tuesday		Wednesday		Thursday		Friday	
		8:00	Review homework	8:00	Review homework	8:00	Review homework	8:00	Wrap up measurements and calculations
8:30	**Introductions, Overview & Quick Tour**	9	**Factors Affecting Mass Measurements *"Little things that make a big difference"***	9	**Uncertainty Calculations SOP 29 & Rounding Traceability GMP 11, 13**	9	Introduction & Demonstration of SOP 8 & Calculations	9	""
10	Math & Conversions	10	**Uncertainty Intro & Accreditation Criteria**	10	**Conventional Mass, Air Buoyancy, Calibration Reports**	10	Application Exercise #5 (SOP 8) Modified Substitution	10	Prepare Summary Report Review, Questions & Answers
11	**Statistics**	11	**Measurement Assurance and Control Charts SOP 9, SOP 30**	11	**Weight Classification ASTM E 617-97, OIML R 111, HB 105-1, GMP 12**	11	""	11	**Balance Characterization HB 44, ASTM E 319, 898, 1270, DKD-7-1**
12	Lunch break	12	Lunch break	12	Lunch break	12	Lunch break	12	Evaluation
1	Application Exercise #1 for Statistics Flask Weighing	1	**Introduction to Weighing Procedures and Mass Laboratory**	1	Introduction & Demonstration of SOP 7 & Calculations	1	**Review, Drift, Choice of Sensitivity Weights**	1	Lab Tour(s)
2	""	2	Application Exercise #2 for Weighing Concepts Direct Reading	2	Application Exercise #4 (SOP 7) Single Substitution	2	Introduction & Demonstration of SOP 4 & Calculations	2	Application Exercise #8 - Large Mass
3	Mean, std dev, causes of variability, Graphic view of data, F test, t-test	3	Application Exercise #3 for Weighing Concepts Sensitivity Test	3	""	3	Application Exercise #6 (SOP 4) Double Substitution	3	Bold: lectures Shaded: hands-on in lab Neither: lab or calculations
4:30	Assign homework Questions	4:30	Assign homework Questions	4:30	Assign homework Questions	4:30	Assign homework Questions	4:30	

Appendix B
Outline of Mass Metrology CD-ROM Project Content

Module codes: Module [number]; Lesson [number]

Module 0

- M0L1 About this Course
- M0L2 Navigating through this Course

Module 1 Section A – Applications for all Measurements

- M1L1 Basic Math
  - Calculators
  - Math Skills
  - Unit Conversions
- M1L2 Statistics
  - Purpose of Statistics
  - Descriptive Statistics
  - Comparative Statistics
- M1L3 Measurement Assurance
  - Concepts and Process
  - Defining & Creating Control Charts
  - Using (& Interpreting) Control Charts
- M1L4 Uncertainties
  - Variability Factors
  - Uncertainty – Calculations for Mass Calibrations
  - Rounding Measurement Values

Module 2 Section B – Basics for a Mass Lab

- M2L1 Mass & Dissemination
  - Traceability & SI Units (concepts + specifics for mass)
  - Physics of Mass & Weighing
  - Calculating Air Density
  - Estimating Buoyancy Corrections
- M2L2 Good Laboratory Practices
  - Quality System Components
  - Mass Laboratory Environment
  - Care, Handling, and Calibration of Mass Standards and Artifacts
  - Laboratory Evaluation
- M2L3 Understanding and Using Balances
  - Operating Characteristics & Specifications
  - Good Weighing Techniques
  - Classification and Operation
- M2L4 Drift & Sensitivity Weights
  - Balance Drift
  - Choosing Sensitivity Weights

Module 3 Section C – Calibration Procedures for Mass

- M3L1 Introduction to Mass Calibrations
  - The Measurement Process
  - Weighing Procedures & Selection
  - Weighing Preparation
- M3L2 SOP 7, Single Substitution
  - Intro
  - Simple
  - Complex
- M3L3 SOP 8, Modified Substitution
  - Intro
  - Simple
- M3L4 SOP 4, Double Substitution
  - Intro
  - Simple
  - Complex
- M3L5 Mass Classifications & Reporting
  - Reporting Mass Values
  - Specifications, Tolerances, & Interpretation

Appendix C – Summary of Lessons & Lessons Learned	
Phases	**Lessons & Lessons Learned**
Background • Provide training since 1990 • Study Education/Training & Technology Overlap (CBT, TBT, E-learning) • Attended SALT Conference • Arranged for provider demonstrations at NIST	+ Understand key terminology for this field: CBT, TBT ASTD ADDIE process ISD SME + Establish a system-wide need + Evaluate "best" technology for each application + Interview potential providers before developing final RFP + See what "can be done"; avoid "page turner" approach (integrate plenty of interactivity)
Develop Request for Proposal • Study procurement web site • Find sample RFPs for CBT/TBT • Talked with procurement staff	+ Work with procurement from the beginning + Use sample SOWs and share resources with others (e.g., WMD Audit Trail) + Anticipate 508-compliancy issues
Schedule/Plan the Project • Management Plan developed by provider with WMD input •	+ Use standard software tools (e.g., Project 98) + Share NIST media design guidelines (WERB requirements for formatting, Internet design style guides, etc.) - Underestimated time & staffing for SME (timeline and milestones)
Develop Content - Planning • Provider developed Learning Analysis Report and Media Design Guide (LAR/MDG)	+ Understand and be able to clarify "learning objectives"

Appendix C – Summary of Lessons & Lessons Learned	
Phases	**Lessons & Lessons Learned**
Writing • Develop initial "Word" document	− Anticipated ISDs could write technical material + Developed Excel outline for graphic of "flow"
Storyboards • Storyboard "Access" document with narration, instructions for programming and graphic designers	+ Experience with Access, Excel, Word, Equation Editor, graphics and embedded objects was essential + Obtained "unlocked" version of database for direct editing and technical review
Video • Selection and taping of video portions	+ Coordinated dry run with staff to practice the flow with each shot with script to allow timing for video to give the video team an idea of what shots they would need + SME went on-site with video subcontractor for synchronizing narration to best video shots
Narration • Contractor planned to use in-house narrator	− Make sure contractor's plans for narration meet your expectations; budget accordingly + Worked with PBA to select alternate narrator and obtain narration files (needed instructions written)
WERB Review • Initial programming was done prior to WERB review so that review could be completed on the "finished product"	− Iterative programming on first two sections caused increase in budget and contractor overruns for programming staff − Underestimated time and process for editorial review (timeline and milestones) − Underestimated time and availability of technical staff (timeline and milestones) + Revised review process; included review of "paper" version + Share programmed sections and style before reviewing "on paper"
Review of Programmed Content • Compare the storyboard and the MDG versus what is "on screen"	− Sometimes hard to imagine the paper to screen transition (editorial, clarity, visual with graphics) − Must constantly review the technical formatting (units, sub/superscripts, formulas)
Next Phase – Translation to Spanish (iteration of entire process)	+ Find "best" format for source material between vendors to enable translation process
Procurement of Translation Services • Translators are on GSA Schedule (even though WMD provided vendors familiar with technical content in SOW and request and they are not always used by other Divisions)	− Become familiar with GSA translation vendors and have them set up demonstrations prior to developing an RFP for a "large" job − Anticipate change in the procurement system (!)

Appendix C – Summary of Lessons & Lessons Learned	
Phases	**Lessons & Lessons Learned**
Translation Provider Methods • Meet with provider to understand process used	+ Provider develops a glossary of technical phrases and terms to use throughout the project for consistency + Provider will work directly with volunteer translators before providing "final" content to us + Make sure bilingual SME's are available + Anticipate difficulty with narration matching text transitions and video
Procure Reprogramming of Spanish Content	– Anticipate changes in the procurement system (!) – Contracting legal review, quality assurance requirements

Appendix D – Sample Topic from Learning Analysis Report

Lesson 2.0—Statistics

Terminal Objective: The learner will identify the purpose of using statistics as a tool to help make decisions about data and will perform basic statistical calculations, such as mean, median, mode, range, standard deviation, F-test, and t-test to analyze and interpret a given data set.

Overview: This lesson will focus on the use of basic statistics in the interpretation of lab data. The introduction will discuss the purpose and use of statistics, using graphics, and animation. The use of each statistical tool in metrology will be demonstrated, using graphics and animations. The learner will then practice statistical calculations, in metrology-related examples.

2.1
The Purpose of Statistics

Enabling Objective: The learner will identify the purpose of using statistics as a tool in the measurement process.

Topics:

a) Definition of statistics
b) Why statistics are used
c) Statistical process (make, analyze, interpret, represent; HB 91)
d) Examples of using statistics

2.2
Descriptive Statistics

Enabling Objective: The learner will perform basic statistical calculations, such as mean, median, mode, range, and standard deviation to analyze and interpret a given data set. [The practice section must enable the analysis and interpretation activity.]

Topics:

e) General normal distribution and dispersion trends of a set of data points (population, sample, histogram, normal distribution)
f) Measures of central tendency: mean, median, and mode
g) Measures of data dispersion: range and standard deviation
h) Concepts: degrees of freedom, accuracy, bias, repeatability and reproducibility

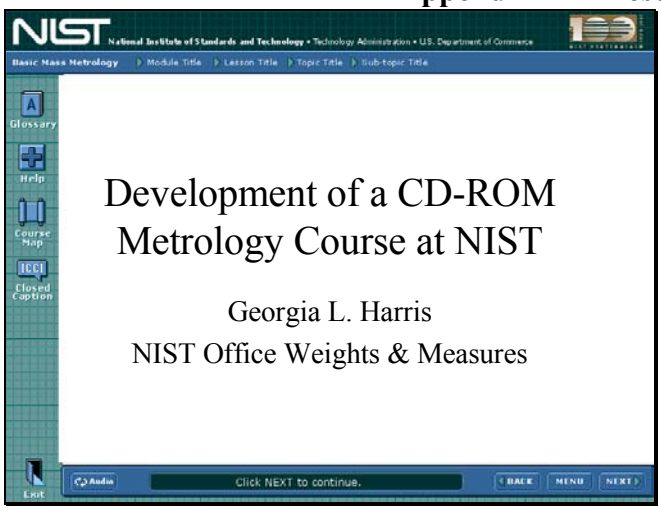
2.3
Comparative Statistics

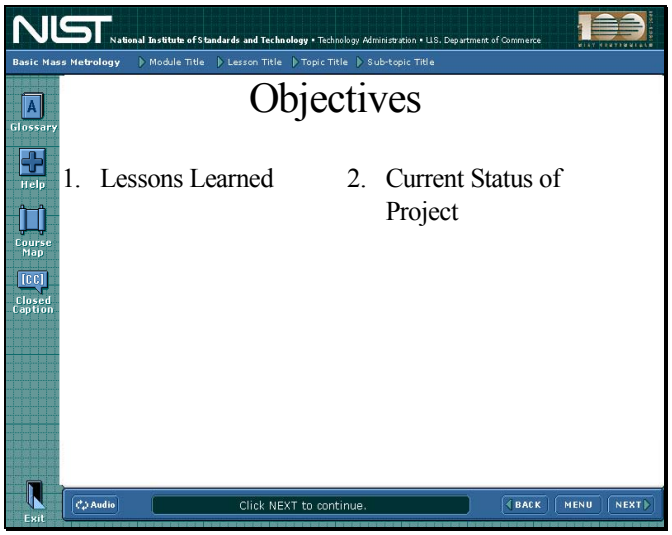
Enabling Objective: The learner will perform the F-test and t-test to evaluate the significance of agreement between the standard deviations and means for given data sets. [The practice section must enable the analysis and interpretation activity.]

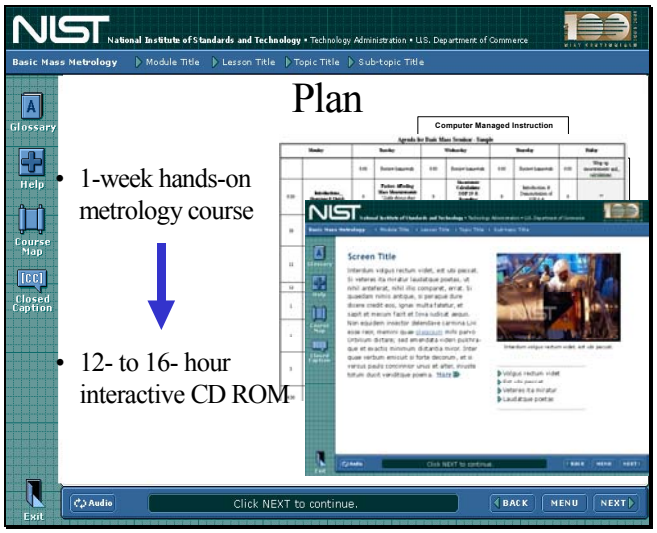
Topics:

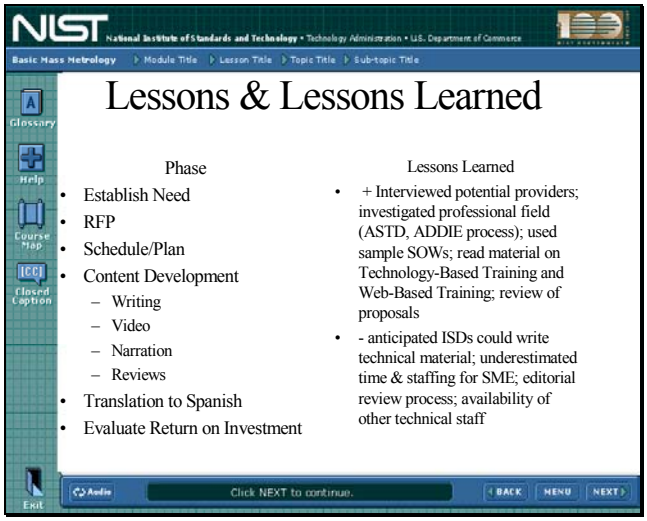
i) Purpose of F-test and t-test
j) Calculating the F-test and t-test for a given data set, using statistical tables

Appendix E – Presentation Slides








National Institute of Standards and Technology • Technology Administration • U.S. Department of Commerce
Basic Mass Metrology
Module Title
Lesson Title
Topic Title
Sub-topic Title
Lessons & Lessons Learned
Glossary
Help
Course Map
Closed Caption
Exit
Phase
Establish Need
RFP
Schedule/Plan
Content Development
Writing
Video
Narration
Reviews
Translation to Spanish
Evaluate Return on Investment
Lessons Learned
+ Interviewed potential providers; investigated professional field (ASTD, ADDIE process); used sample SOWs; read material on Technology-Based Training and Web-Based Training; review of proposals
- anticipated ISDs could write technical material; underestimated time & staffing for SME; editorial review process; availability of other technical staff
Audio
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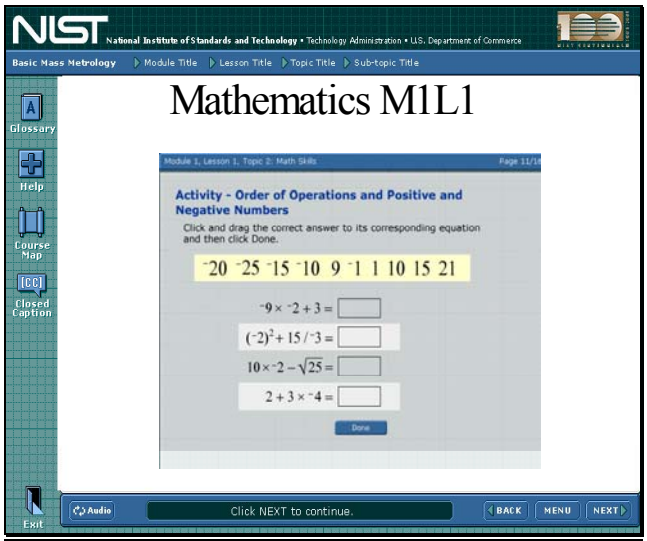
National Institute of Standards and Technology • Technology Administration • U.S. Department of Commerce
Basic Mass Metrology
Module Title
Lesson Title
Topic Title
Sub-topic Title
Mathematics M1L1
Glossary
Help
Course Map
Closed Caption
Exit
Activity - Order of Operations and Positive and Negative Numbers
Click and drag the correct answer to its corresponding equation and then click Done.
-20 -25 -15 -10 9 -1 1 10 15 21
-9 × -2 + 3 =
(-2)² + 15 / -3 =
10 × -2 − √25 =
2 + 3 × -4 =
Done
Audio
Click NEXT to continue.
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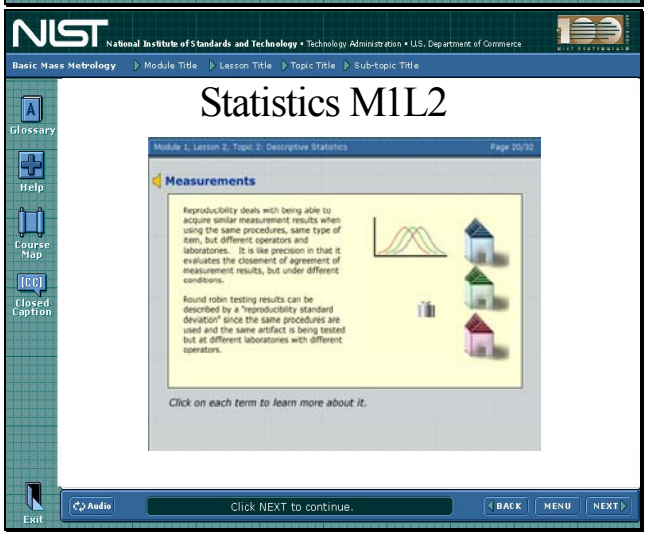
National Institute of Standards and Technology • Technology Administration • U.S. Department of Commerce
Basic Mass Metrology
Module Title
Lesson Title
Topic Title
Sub-topic Title
Statistics M1L2
Glossary
Help
Course Map
Closed Caption
Exit
Measurements
Reproducibility deals with being able to acquire similar measurement results when using the same procedures, same type of item, but different operators and laboratories. It is like precision in that it evaluates the closement of agreement of measurement results, but under different conditions.
Round robin testing results can be described by a 'reproducibility standard deviation' since the same procedures are used and the same artifact is being tested but at different laboratories with different operators.
Click on each term to learn more about it.
Audio
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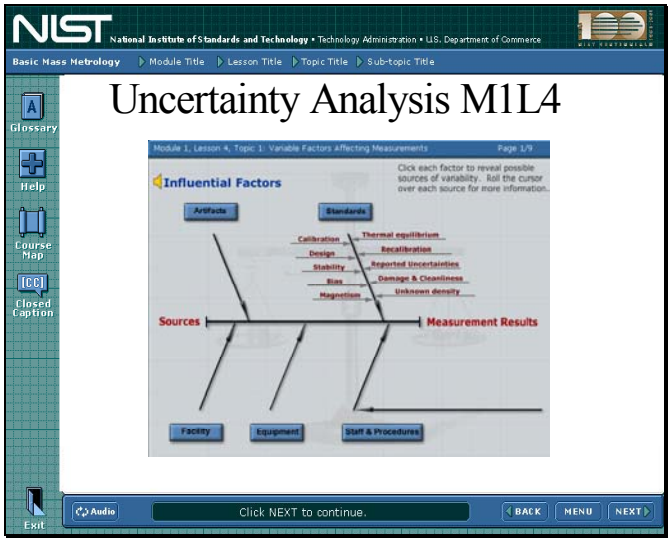
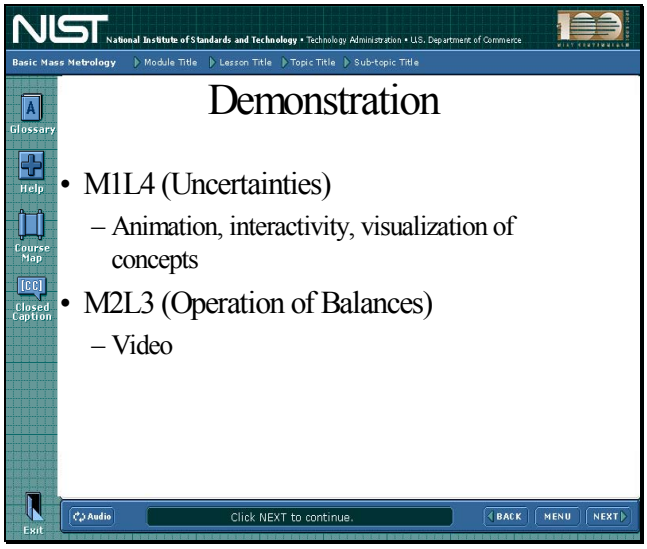
Uncertainty Analysis M1L4

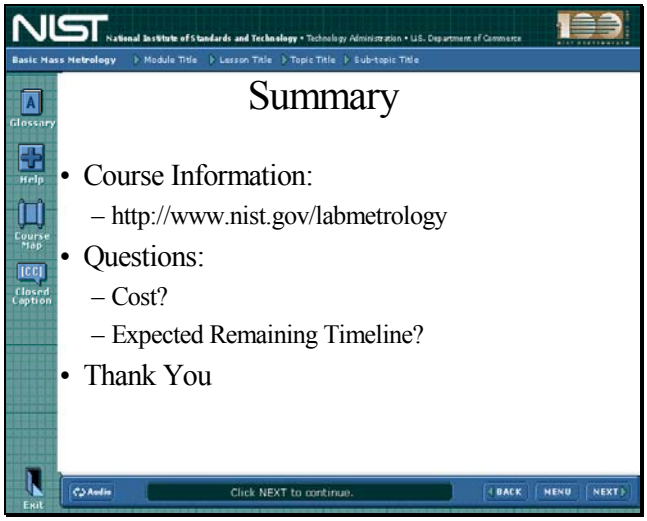


Good Laboratory Practices M2L2

Demonstration

- M1L4 (Uncertainties)
  - Animation, interactivity, visualization of concepts
- M2L3 (Operation of Balances)
  - Video




National Institute of Standards and Technology • Technology Administration • U.S. Department of Commerce
Basic Mass Metrology
Module Title
Lesson Title
Topic Title
Sub-topic Title
Glossary
Help
Course Map
Closed Caption
Exit
Summary
• Course Information:
– http://www.nist.gov/labmetrology
• Questions:
– Cost?
– Expected Remaining Timeline?
• Thank You
Audio
Click NEXT to continue.
BACK
MENU
NEXT