

Metrology Outreach and Training: A Fulbright Experience in Mexico

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Abstract

2016 was an exciting year for international collaboration on metrology education and training. This paper provides a 3-part look at how a Fulbright Specialist grant supported collaboration between the United States and Mexico. Part 1 describes the experience of Georgia Harris (NIST) as a Fulbright Specialist, from the application process to the implementation activities in Mexico and shares insight about lessons learned and benefits to NIST. In Part 2, Flora Mercader and Adriana Veraza describe the application process within the University to obtain approvals for the grant, the implementation process, how additional parties were engaged for participation, some immediate benefits, some expected long-term impacts, and lessons learned. Part 3 includes Salvador Echeverria's description of CENAM's involvement in the courses conducted at the University as well as the sessions held at CENAM, immediate benefits that were observed, and provides insight for ongoing collaboration for metrology education and training in Mexico. Recommendations and additional ideas for international collaboration and future work on measuring the impact of collaborative efforts are proposed.

1. Introduction

The Fulbright Specialist Program is managed by the United States Department of State, Bureau of Educational and Cultural Affairs Exchange Programs. The Fulbright Program is an international educational exchange program sponsored by the U.S. government and is designed to increase mutual understanding between the people of the United States and the people of other countries. *“The Fulbright Specialist Program sends U.S. faculty and professionals to serve as expert consultants on curriculum, faculty development, institutional planning, and related subjects at academic institutions abroad for a period of two to six weeks. The Fulbright Specialist Program allows overseas universities, cultural centers, non-governmental organizations, and other institutions abroad to develop collaborative projects which host a leading U.S. academic or professional at their institution to work on diverse, short-term collaborative projects focused on education and training. These projects support critical priorities identified by the host institutions and supported by U.S. embassies and binational Fulbright Commissions abroad.”*¹

¹ Fulbright Specialist Program details are available online at: <https://exchanges.state.gov/us/program/fulbright-specialist-program>. For details about applying to become a Fulbright Specialist, you can visit: <https://fulbrightspecialist.worldlearning.org/eligibility-specialists/> (2017-04-16).

Requests for U.S. National Institute of Standards and Technology (NIST) to conduct training at the University were initially received by Ms. Carol Hockert, Chief of the Office of Weights and Measures while attending a Centro Nacional de Metrologia (CENAM) Symposium (CENAM Simposio) session in Mexico in 2014. After discussions related to the normal costs of organizing the NIST Fundamentals of Metrology² seminar, both in terms of the logistics/operational costs to NIST and the travel/per diem costs of the attendees, the discussions stalled due to excessive costs of providing the program on site in Mexico.

The idea to use the Fulbright Specialist Program as a collaborative tool was initially raised during discussions Ms. Georgia Harris had at the American Society for Engineering Education (ASEE) conferences where staff managing the Fulbright Specialist Program were recruiting potential experts for international collaboration opportunities. Ms. Harris then suggested to Dr. Flora Mercader, Universidad Politécnica de Santa Rosa Jáuregui (UPSRJ), the idea of coordinating the requested training through a Fulbright Specialist Program. The difference between the Fulbright Scholar and Fulbright Specialist program is that the former is a student and the latter is a professional expert providing instruction and consultation. One major advantage of the program is that of cost-sharing and funding sources.

The activities described in this paper were funded through a mixture of financial sources, including the Fulbright Specialist Grant awarded to Ms. Harris which covered flight expenses to and from Mexico; the U.S. National Institute of Standards and Technology (NIST), which covered staff time and course materials; the Universidad Politécnica de Santa Rosa Jáuregui (UPSRJ), which covered all in-country expenses associated with transportation, food, and lodging, plus the local coordination of logistics, space, and materials; and the Centro Nacional de Metrologia (CENAM), which hosted a coordinated effort for portions of the sessions held at CENAM. In addition, course equipment and standards were provided by Sartorius Corporation, Troemner, LLC, and Ms. Harris. Because Ms. Harris was working for NIST at the time of the grant/project, she was ineligible to receive the per-diem allotment that is available to other grantees.

2. Fulbright Specialist Perspectives

2.1. Application

Basic eligibility requirements are available on the Fulbright Specialist program website. But in general, applicants must be U.S. citizens, have significant experience in their respective field, as demonstrated by professional, academic, or artistic achievements, and able to travel overseas for 14 to 42 days (length varies depending on project). The application process consists of an on-line application, including curriculum vitae (CV) and submission of two letters of reference.

Once the application has been submitted by one of several annual deadlines, there is a peer-review process that assesses: professional qualifications (professional standing and other

² Fundamentals of Metrology, seminar descriptions are available here: English: <https://www.nist.gov/pml/weights-and-measures/fundamentals-metrology>. Spanish: <https://www.nist.gov/pml/weights-and-measures/fundamentos-de-metrolog%C3%ADa>

achievements), demonstrated capacity for leadership within their field, suitability for Specialist Grant activity, alignment of candidate's background and skills with their objectives for the program outlined in the candidate's application essays, feasibility of the candidate to successfully engage in eligible grant activities, quality of the submitted references, cross-cultural communication skills and adaptability, quality of previous international/intercultural experiences, and the likely overall benefit to stakeholders, including potential to contribute to a host institution, benefit to the home institution (NIST in this case), and potential for advancement of knowledge in the applicant's field of study and personal qualities to successfully complete a project designed by a host institution abroad and to serve as a cultural ambassador for the United States. A successful peer-review process places the applicant on the Fulbright Applicant Roster. Once a project and grant are approved, the applicant is then awarded a "Fulbright Specialist Grant."

The grant authorization describes the status, for example: "Georgia Harris has been selected by the J. William Fulbright Foreign Scholarship Board for a FULBRIGHT SPECIALIST GRANT under the provisions of the Mutual Educational and Cultural Exchange Act of 1961 (as amended), the FULBRIGHT PROGRAM. This grant is administered by the Bureau of Educational and Cultural Affairs, United States Department of State with the cooperation of the Institute of International Education/Council for International Exchange of Scholars (IIE/CIES)."

The application process, is simple and straightforward.

2.2. Project Development (Statement of Work)

Host institutions are required to lead the project development process. This ensures that expertise requested through the Fulbright Specialist Program meets a need that the institution has self-identified as a critical area for its growth and development. For the activities described here, the collaboration and discussions about potential projects had already taken place. So, while potential Fulbright Specialists are permitted to explore collaborations with potential host institutions, host institutions are under no obligation to consider such requests. Host institutions who ultimately elect to name a Fulbright Specialist candidate on their project proposal must include a strong justification for the need to work with this candidate and for all proposed activities.

The proposed statement of work built on potential courses that Ms. Harris has previously taught and that the University determined would be of greatest value in Mexico. Ms. Harris provided the related course descriptions and learning objectives for the project proposal to ensure that the host university needs were met with materials that could be successfully delivered.

2.3. Planning for Materials, Logistics, Equipment, and Standards

The courses that were selected by UPSRJ and included in the Project Proposal were designed to be conducted at alternative facilities and locations. Therefore, logistics details and host instructions were readily available. The most challenging aspect associated with the advance coordination of logistics was communication regarding the materials needed for a successful training event. A preliminary list of measuring equipment, standards, and other instructional

materials were provided to UPSRJ. When most aspects of the equipment and standards were identified as not being readily available, alternative sources were sought. Small hand tools, like micrometers, pocket balances, and items to be measured (in this case pennies), were shipped with the training materials from NIST. UPSRJ provided a local computer printer for printing draft calibration certificates during the course, and was made available for use by the students.

All course notebook and handouts, along with printing instructions, were sent electronically to the University in advance of the sessions to be printed by the University and then provided to the students on-site. This process of providing electronic media has worked well for the Fulbright Specialist at other training events previously conducted in Colombia. Additional resources were hand-carried, such as multiple copies of a USB “technical library.”

A few incidental instructional resources, such as easels to hold flip chart paper were not readily available at UPSRJ or for purchase at the local office supply store, but could have been shipped with other supplies from NIST since this type of material is routinely shipped for conduct of off-site training events. Having some experience with international shipments, there was some concern about materials not being received in a timely manner. However, the shipping to and from the training site worked extremely well and all materials that were shipped arrived on time and without damage or incident. Materials returned to the U.S. were also returned without undue delay or problems.

2.4. Conducting the Fundamentals of Metrology Course and Lessons Learned

Dr. Mercader was the primary technical contact with the UPSRJ for collaboration. She arranged campus access on the Sunday prior to beginning of the first course to the classroom and the laboratory, which were then set-up. Advance access to the campus classroom and laboratory alleviated some of the stress associated with teaching a course in an unknown location. Even though everything was available and arrived on time, flexibility and creativity were called for on the first day. Everyone arrived to find that the facility was experiencing an electrical power outage! The host was quickly able to acquire an electric generator to power the instructor laptop and projector to initiate the course on time!

One of the key observations for the course and this audience is that the Fundamentals of Metrology curriculum is normally framed around operating a calibration or testing laboratory per the ISO/IEC 17025 documentary standard³. Because the training participants were professors and instructors of metrology, most were not currently working in a calibration laboratory, which is why the documentary standard was assigned as pre-reading. Several participants previously worked at CENAM or in industry calibration laboratories and were familiar with these concepts. Participants of this course are usually required to pass a mathematics pre-test. This requirement was waived for this audience of engineering professors, which did not result in any problems for the successful completion of the course. Several of the usual examples that are provided in the Fundamentals of Metrology course, such as “internal auditing” were shifted to “internal auditing to accreditation requirements” to share the ideas and concepts. Several minor shifts and exceptions were made due to this audience being primarily engineering professors. Instead of

³ ISO/IEC 17025: 2005, *General Requirements for the Competence of Testing and Calibration Laboratories*.

teaching how something would be applied in a calibration or testing laboratory, emphasis was placed on how to teach the content to subsequent students who would be applying the material in a training laboratory and ultimately on-the-job.

The other challenge that required flexibility and creativity were related with teaching using English language. Having better Spanish language skills would have been a definite advantage. However, the engineering professor participants as well as their engineering programs are considered bi-lingual (Spanish/English) and the course was intentionally taught in English so that participants would have the instructional experience from an English speaker, using their primary language. The course is normally divided into small groups. During introductions, the instructor made an initial assessment of English language skills to help divide students into their teams. At least one highly proficient English speaker was on each team to ensure that the debriefing process associated with each activity would be successful. Most activities and hands-on measurements were conducted in the student's preferred language with summaries and debriefing conducted in English.

2.5. Conducting Project Based Learning Train the Trainer Seminar and Lessons Learned

The second major course conducted as a part of the Fulbright Specialist project was a Project Based Learning Train the Trainer seminar that focused on application to Metrology instruction for engineering professors. Ms. Harris has previously conducted Train the Trainer events at a CENAM Symposium and at several metrology training events within the United States. As a part of engineering outreach efforts, Ms. Harris has presented hands-on metrology training concepts to engineering professors at the previous American Society for Engineering Education (ASEE) conferences⁴. The 2.5 day seminar combined perspectives of adult learning, Train the Trainer activities, and outreach to engineering professors, and focused on the use of the ADDIE Instructional Design (ID) model⁵, developing effective course learning objectives, designing hands-on practical exercises for teaching metrology concepts, and sharing ideas for practical hands-on activities among the participants.

Additional benefit could be gained in future sessions by obtaining the reference documents and instructional models that professors may be required to use when developing engineering curricula. The learning objective development process is standard, but the ADDIE model, while often used for instructional design efforts, is not always the method used in all universities. A preliminary web search determined that the ADDIE model is in common use among universities and is also used in the NIST training program, which is why the model was presented; however, several other participants noted that they were required to use alternative models in their work environments.

⁴ Incorporating Adult Learning Methods and Project Based Learning in Laboratory Metrology Courses, Georgia L. Harris, ASEE Annual Conference and Exposition, 2013.

⁵ The ADDIE Instructional Design (ID) model is a framework for designing and developing educational and training programs, originally developed in 1975 by Florida State University's Center for Educational Technology (Branson, Rayner, Cox, Furman, King, Hannum 1975; Watrson, 1981) for the U.S. Army. "ADDIE" stands for the five steps: Analyze, Design, Develop, Implement, and Evaluate.

The integration and application of adult learning and project-based learning (PBL) concepts as a part of these course provided an opportunity for each professor to experience and observe the impact of an alternative to a traditional lecture-based course. Significant feedback was received from the participants on the value of experiencing the ideas in action and participating in the technical courses themselves. This concept is routinely integrated in NIST Office of Weights and Measures courses, resulting in significant improvement of students applying concepts on the job, rather than just gaining knowledge or familiarity.

During the events held in Mexico, it was possible to observe the level of comprehension of engineering professors related to metrology; they also provided feedback that the course provided them with extensive insight in metrology that was greater than their previous experience provided. Several professors reported that while they have been working in metrology and engineering for many years, they gained additional useful insight about teaching metrology concepts. Even though many of the professors had a background in metrology, little hands-on measurement exercises have been integrated into the engineering curricula. In other cases, applying metrology to engineering is much further ahead of many U.S. engineering programs. For example, Mexico has numerous vocational and higher education organizations providing courses in metrology, including the integration of metrology within engineering programs. Because most of the participating professors were from recently established universities, they now have opportunities to create and integrate metrology concepts and hands-on activities into their curricula before the programs become entrenched in lecture based methods and become less flexible. That is, there is a tendency to leave a course as it is designed to minimize the additional effort that could be required if incorporating major changes, or even continual improvement, both of which might require accreditation body or governmental assessments of curriculum changes.

2.6. Outreach to University Students and Observations

Two key outreach sessions were provided to UPSRJ students to increase their awareness of measurement science career opportunities and leverage the metrology expertise of the Fulbright Specialist while on campus. The first technical topic explored metrological traceability and included a discussion of “who’s who” in the world of metrology. About 25 or 30 third and fourth year engineering students participated in this session. The students were engaged in the topic and asked insightful application questions. About 80 first year engineering students participated in the second technical session, “How Do You Know Your Measurements are Right?” Concepts such as traceability, calibration, and uncertainty, using a theme of temperature were presented. The presentation highlighted Mexican women metrology scientists and engineers as well as several women students currently studying within the UPSRJ industrial metrology engineering program. Much world-wide Science, Technology, Engineering, and Mathematics (STEM) outreach is targeted to young women to encourage them to pursue and stay in technical fields. Identifying suitable role models and available mentors is critical to demonstrating that women can be successful in STEM careers. While targeting young women was not a specific goal of the Fulbright Specialist project proposals, it is a key aspect of the outreach work conducted by both Dr. Mercader and Ms. Harris.

It was extremely rewarding to observe the excitement among the engineering students about metrology! It was refreshing to observe a high number of young women enrolled in the program, as well as the overall interest expressed by outreach session attendees. Students who approached Ms. Harris after the sessions were primarily interested in hearing more about metrology careers.

2.7. Participating at CENAM Sessions and Insights

Dr. Mercader coordinated with Dr. Echeverria to have Ms. Harris participate in several technical sessions at CENAM with the final plan and agenda coordinated during the Fulbright Specialist project visit to Querétaro. The two sessions previously presented to students at UPSRJ (“How Do You Know Your Measurements are Right?” and “Essentials of Metrological Traceability”) were presented at CENAM, with the idea that the content could be used as a model for agency scientific staff to conduct local outreach with students (rather than as technical content focused on the participants themselves).

Of most interest during the CENAM visit was a session on Best Practices in Metrology Instruction, with additional participants from CENAM (Ismael Castelazo, General Director of Technology Services), UPSRJ (Flora Mercader), and The Metrology School (Hugo Hernández), which was attended by about 50 CENAM staff and students. The presenters during the Best Practices session primarily shared details about their programs and courses. Rather than talk about NIST training activities, personal insights about “five best practices” were shared as had previously been discussed with Dr. Echeverria. The Fulbright Specialist expressed personal opinions and experiences regarding the five best practices:

1. Instructors should participate in instructor professional development, such as in the concepts of adult education and instructional design (a technical PhD alone is insufficient).
2. Course design must include the integration and alignment of learning objectives, activities, and student assessments. Students must be assessed on stated objectives and learning methodology must be consistent with expectations.
3. Adult learning processes and concepts need to be used at the university and post-university level (i.e., andragogy versus pedagogy).
4. Ongoing evaluation is required for all course content and educational activities to ensure continual improvement and to remain current. For example, a course developed on ISO Guide 25: 1990 would not be applicable for a course that implements ISO/IEC 17025:2005.
5. Metrology training and education programs benefit from some level of accreditation to raise the quality bar and professionalism.

2.8. Final Report Required

After a Fulbright Specialist completes the project, a final project report is required to be submitted. It includes an opportunity to identify lessons learned and benefits for all the participants. Information, much like was in this paper, was submitted as a part of the final report. Of specific interest is the intent to conduct ongoing collaboration and evaluate the long-term impact of the Fulbright Specialist project.

2.9 Benefits to NIST

Collaboration in metrology education and training helps fulfill NIST objectives by maintaining international leadership, ensuring the acceptance and use of international and U.S. documentary standards, and dissemination of NIST measurement procedures and metrology training methods, thus helping to ensure a solid measurement foundation in academia, government, and industry throughout the Americas. Part of the Office of Weights and Measures (OWM) mission is to “improve the accuracy of measurements, enhance consumer protection, foster fair competition, and facilitate economic growth and trade through technical activities that promote uniformity in national and international legal metrology laws, regulations, standards, test procedures, and enforcement.” Much of the OWM efforts include publication of measurement procedures and training on those procedures for the weights and measures and metrology communities. Many NIST documents were referenced and used during the events.

The OWM training program is accredited by the International Association for Continuing Education and Training (IACET) which requires use of adult-learning methodologies. Having participants in the courses, who are metrology professionals as well as university professors, provided unique feedback and insights to the Fulbright Specialist that will be applied when updating OWM metrology courses. Gaining experience working with professors, and finding out their unique challenges in academia, will also help with ongoing effort and metrology outreach work that is being coordinated with professors at U.S. schools of higher education through association with NCSL International and ASEE.

3. Universidad Politécnica de Santa Rosa Jáuregui (UPSRJ) Perspectives

Universidad Politécnica de Santa Rosa Jáuregui (UPSRJ) is a higher education institution with public funding founded in 2011. UPSRJ is part of a network of Polytechnic Universities in Mexico with a high degree of specialization in the field of engineering. The academic program of Industrial Metrology Engineering was designed at UPSRJ, thus becoming the first University in Mexico to offer this educational option which has remarkable industrial requirements. To ensure that the professors who teach in this program are kept up-to-date and aware of the importance of metrology, the University is constantly looking for associations with institutions and experts who can contribute their experience and knowledge to the program. The interaction of UPSRJ students and teachers with foreign experts is also a way to expand the internationalization program on campus.

3.1. Application for a Fulbright Specialist Project

In 2012, Dr. Flora Mercader, (UPSRJ) and Ms. Georgia Harris, (NIST) met at the Metrology Symposium organized by the National Metrology Institute of Mexico (Centro Nacional de Metrología, CENAM Simposio). Both identified that they are carrying out activities to strengthen the teaching of metrology to future generations. Several opportunities for collaboration were considered. However, the Fulbright Specialist program was identified as a potential cost-sharing opportunity for the University to have short-term collaborative projects with highly experienced specialists.

The application process to obtain the expert was simple and straightforward. The success of the program was that we could determine exactly who the expert would be, which made the process much easier. Dr. Mercader Trejo and Ms. Adriana Veraza contacted Dr. Jackal Taleorn at La Comisión México-Estados Unidos para el Intercambio Educativo y Cultural (COMEXUS), which manages the Fulbright program in Mexico. Dr. Taleorn explained the application process and the deadlines for delivery of the application format. We told him about Ms. Harris, the expert we had in mind. Once he checked that Ms. Harris was among the pool of registered experts, he explained the process.

3.2. Logistics and Challenges at UPSRJ

An estimate of costs and expenses of the program was made during the planning phase. Once U.S. Fulbright Program replied that the project was possible with the requested expert, the project was presented in detail with the budget and dates to Mr. Enrique Sosa Gutiérrez, UPSRJ Rector, and Orfelinda Torres Rivera, the academic director, explaining the scope and impact to teachers and students and for the University itself. The academic directors and the rector together decided to present a proposal date, which was presented to Ms. Harris to initiate event scheduling to finally make the project a reality.

Dr. Mercader and Ms. Harris developed the scope of work, which presented high level detail of the program content and required resources required for the visit. All the presentations, conferences, and courses would be combined in an event called “Metrology Seminar.” The activities of the seminar are described in the following table. Dr. Mercader and Ms. Harris reviewed and selected courses and topics that would be of benefit to the participants in Mexico.

Table 1. Fulbright Specialist Program Metrology Seminar Components.

Activity	2016 Dates	Participants
COURSE “Fundamentals of Metrology”	Oct 31 to Nov 07	4 Professors from UPSRJ, 1 from UNAQ, 1 UTSJR, 1 UPG, 1 UPQ, 1 ITC, and 2 from CENAM
CONFERENCE "Essential Elements of Metrological Traceability"	Nov 07	Second and third year students from the Industrial Metrology Engineering Program
COURSE "Project Based Learning Applied to Metrology Instruction"	Nov 08 to 10	Professors from UPSRJ and guests from different institutions
CONFERENCE "How do you know your measurements are right?"	Nov 10	First year students from the Industrial Metrology Engineering Program
CONFERENCE "Essential Elements of Traceability and Risks; How do you know your measurements are right"? and Best Practices in Metrology Education and Training Panel"	Nov 11	CENAM

Ms. Harris provided a detailed list of the materials, equipment, standards, and teaching resources that would be needed to effectively conduct the seminars in Mexico, and the University then conducted an inventory of materials. The project preparation before the specialist’s arrival was a challenge because the UPSRJ currently does not have all the required course laboratory equipment. Ms. Harris and Dr. Mercader contacted research centers and institutions to request

support for equipment loans. UPSRJ is a recently created institution, founded less than 6 years ago. Because the organization is in the development stage, facilities and equipment infrastructure is deficient. One of the biggest challenges UPSRJ faced was having the necessary equipment, standards, and materials for the metrology seminar. One way to solve it was to collaborate with training attendees to bring typical course equipment and calibration artifacts, which included certified mass standards, thermos-hygrometers, and certificate gage blocks. In addition, Ms. Harris contacted companies that supply analytical balances and mass standards, (such as Sartorius, Troemner LLC) exploring the possibility of lending or donating balances, mass standards, and other laboratory resources for the seminar. Sartorius gave us a positive answer and provided 4 analytical balances with the characteristics that were needed for the seminar. Sartorius staff were also available on site to talk to the participants and students of the University before/after the sessions and during breaks. Another very important contribution was the donation of three sets of OIML Class F₂ mass standards (100 g to 1 mg) with NVLAP accredited calibration certificates from Troemner, LLC.

Another challenge for the university was the space and materials to teach the courses. Many of the materials normally used to teach the respective seminars were not available and the room configurations were not ideal. However, despite having the students and the specialist move to several rooms on campus, the sessions were still successful. Once the university staff moved other scheduled courses to alternative locations, the group could minimize the use of multiple classrooms and could use a regular classroom that was located very near the laboratory.

The International Department, headed by Ms. Veraza, oversaw preparing the lodging, food, transportation, and course materials prior to the arrival of Ms. Harris. This aspect was less challenging and worked very smoothly. The necessary course material for the participants was sent electronically in advance for preparation of notebooks and handouts for the participants. The University also generally prefers to conduct courses in a sustainable manner, with less “paper” and requested Ms. Harris to consider not using printed course materials. However, Ms. Harris responded that the course activities required review and mark-ups of some of the materials, designed to emulate the typical process performed in an operational laboratory, and had not designed the course to meet sustainability goals.

3.3. Collaboration with additional Universities, Industry, and CENAM

To extend the impact of Ms. Harris' visit as a Fulbright Specialist, UPSRJ invited professors from other universities and institutions. The invitation was extended to institutions that are part of the Network for Innovation and Research in Metrology for the Automotive Industry (RIIMSA), which is coordinated by UPSRJ. The following additional seven RIIMSA member institutions were represented through their staff: Centro Nacional de Metrología (CENAM), Centro Regional de Optimización y Desarrollo de Equipo (CRODE), Universidad Politécnica de Guanajuato (UPG), Centro de Ingeniería y Desarrollo Industrial (CIDESI), Centro de Investigación y Asistencia Técnica del Estado de Querétaro (CIATEQ), Universidad Politécnica de Querétaro (UPQ), Universidad Aeronáutica en Querétaro (UNAQ), Universidad Tecnológica de San Juan del Río (UTSRJ).

Additionally, participants from the following three institutions attended: Universidad Anahuac Campus Querétaro, Universidad Tecnológica de Querétaro (UTEQ), Instituto Tecnológico de Celaya (ITC). It is important to emphasize that CENAM support was essential for this event to be successfully developed and implemented. Good relationships were also developed between Sartorius, Troemner and the university due to the donations of equipment and standards.

3.4. Visit Logistics

The University oversaw transporting the specialist during the entire visit, from Ms. Harris' arrival at the airport until her return. Accommodation and meals were also covered by UPSRJ. For the seminar, University staff were aware of the lectures and courses for any need that arose. Regarding laboratory practices, Dr. Mercader served as an assistant to Ms. Harris, providing guidance to the professors who were attending the course.

3.5. Immediate Benefits

Several immediate benefits were achieved:

- Greater collaboration among Queretaro regional universities and metrology institutions interested in improving their capabilities in teaching metrology through networking and team activities conducted during the courses.
- UPSRJ obtained a good supply of equipment and calibration artifacts useful for hands-on metrology practices, through the donation of balances, calipers, gage blocks, weight sets, pocket balances.
- Metrology and adult learning concepts were improved for training and developing professors who are teaching metrology topics.
- Increased metrology exposure for university students who are studying engineering in industrial metrology to see the importance and impact of measurement science.
- Educational tools and models that can be used to improve the metrology curricular contents through project-based learning methods were developed.

3.6. Expected Long-term Benefits

One of the most important benefits of these courses was the opportunity to positively impact how metrology is taught for future generations. This is one of the UPSRJ's priority objectives. Through the training that was provided, professors are already implementing actions to improve the metrology teaching methods both at the University and in at the other institutions that participated in the seminar. Following the seminar, several instructors have contacted Ms. Harris to request clarification and additional resources related to those provided during the course sessions.

3.7. Lessons Learned and Insights Gained

The primary lesson learned from this great experience was that there are many ways to overcome obstacles and barriers to effective metrology instruction – especially those due to the lack of equipment and standards and limited classroom spaces. Ms. Harris's availability prior to, during, and after the seminar provided for a resoundingly successful event.

4. CENAM Experience

4.1. Role and function of CENAM in the project.

CENAM, the *Centro Nacional de Metrología*, is the National Metrology Institute (NMI) of Mexico. As such, it is the representative of Mexico in the International Committee on Weights and Measures (CIPM) and signatory of the Mutual Recognition Arrangement (CIPM MRA) which is the framework through which NMIs demonstrate the international equivalence of their measurement standards and declare the calibration and measurement certificates they issue. CENAM was created by the Federal Law on Metrology and Standardization (1992) which assigns to the Center, among others, the following functions:

Federal Law on Metrology and Standardization (LFMN) of Mexico, Chapter V (Centro Nacional de Metrología), Article 30 (Functions) states CENAM:

- I. To be the primary Laboratory of the National Calibration System.
- IV. To promote and develop research and technological development activities in different fields of metrology, as well as to collaborate in the development of human resources with the same objective.
- VIII. To organize and participate, if convenient, in congresses, seminars, conferences, courses and other type of events related to metrology.
- IX. To sign agreements with research and institutions that have capabilities to develop primary standards or high precision instruments, as well as education institutions that can offer specializations in metrology.

As can be seen, CENAM has the mandate by law to collaborate with Higher Education Institutions for developing competencies regarding metrology. In addition, the high value that collaboration with NIST and the UPSRJ provide to this mandate, has been clear since CENAM's founding.

The long-standing collaboration and support received by CENAM from NIST scientists and specialists have been always recognized. In this case, the interaction with Ms. Georgia Harris and Ms. Carol Hockert through the NCSL International⁶ Learning and Development Committees, has led to very fruitful results. An indicator of this is the number of papers published in the NCSLI Workshop and Symposium by members of the Mexican community, most times promoted by Ms. Georgia Harris in her work as leader of the NCSLI Learning and Development Committees.

In the Mexican scene, the fact that the training program in metrology and quality developed by the UPSRJ was the pioneer in the educational field, makes this university an ideal partner to fulfill the function and the objectives in terms of human resources development in metrology as outlined earlier.

⁶ NCSL International (NCSLI) – formerly National Conference of Standards Laboratory. More information about NCSLI can be viewed at www.ncsli.org.

The Metrology Outreach and Training program, promoted by the UPSRJ and supported by the Fulbright Specialist Program of the U.S. Department of State, has been seen by CENAM as a great opportunity that has demonstrated its benefits.

4.2. Coordinating an Event at CENAM

The coordination of the event at CENAM was very straightforward, because Ms. Georgia Harris has much experience, both technical and logistical, in these types of events, with the specifics of the event regarding cultural adaptation and CENAM logistics where well cared for by Dr. Mercader and her team. Details of the planning process were provided in section 2.7. The final selection of activities for the CENAM journey were defined in common agreement among Ms. Harris, Dr. Mercader and Dr. Echeverria. This was as follows:

Table 2. Fulbright Specialist Program Metrology Seminar Program in CENAM, Nov 11, 2017..

Activity	Objective	Participants
TALK: How do you know your measurements are right?	To realize, for different types of public, the role of measurement uncertainty in their own activities.	Instructor: Ms. Georgia Harris. Participants: PhD Students of the Autonomous University of Querétaro. Metrologists and scientists of CENAM.
TALK: Essential Elements of Metrological Traceability.	To provide elements for judgement regarding measurement traceability and its implications, including risk.	Instructor: Ms. Georgia Harris. Participants: Metrologists and scientists of CENAM. Metrologists and staff of secondary laboratories.
PANEL: Best Practices in Metrology Education and Training.	To reflect and share experiences in the exploration of new approaches of metrology education and training.	Coordinator: Dr. Ismael Castelazo, CENAM. Panelists: Ms. Georgia Harris, NIST. Dr. Flora Mercader, UPSRJ. Mr. Hugo Hernandez, Metrology School Participants: CENAM metrologists and University Teachers.
TALK "Project Based Learning Applied to Metrology Instruction"	To share principles and best practices related to the NIST approach for metrology instruction: five best practices	Instructor: Ms. Georgia Harris Participants: CENAM metrologists hat offer training. University Teachers related to the field.

4.3. Inviting students and staff

The invitation to students and staff was straightforward. Students that attended the CENAM event were mainly from the Autonomous University of Queretaro that are in postgraduate programs (MS and PhD) in different fields of engineering. Many of them have undertaken the course of “Measurement in the Research Process” given by Dr. Echeverria. The topic of “How do you know your measurements are right” was immediately interesting for them. From that, the topic of “Essential Elements for Metrological Traceability” followed for logical association.

Another group with great interest in most topics regarding teaching, training and learning was that of metrologists who, among their functions, provide courses and training in metrology.

Naturally, most of them were from CENAM, because that was the main interest of the Center, but also metrologists from other calibration laboratories attended with interest.

Overall there were more than 50 attendants, besides the speakers and organizers, in the various sessions, and their evaluations of the event were “excellent” and “very useful”.

4.4. Creating a Panel to discuss Best Practices in Metrology Education and Training

Metrologists that provide different types of education and training are very interested in exploring new training techniques. In Mexico, most metrologists are experts in some specific discipline, or in some of them, but not necessarily experts in education or training. The possibility of having Ms. Harris in Mexico, with a significant expertise in education, training, learning and development in metrology, offered the best opportunity to share her experience with others interested in this important function. The other panelists also offered important experiences. Dr. Ismael Castelazo presented aspects of the CENAM experience in continuous education in metrology. CENAM has followed mostly traditional ways of teaching, but has a long experience from its beginning (1994) of about 50 courses a year in different themes of metrology. It is important for CENAM to identify the most valuable of learning experiences and nurture them with other experiences as those presented in the panel. Dr. Flora Mercader, with a strong experience in metrology at CENAM and abroad, has been one of the architects of the Metrology Program at the UPSRJ and has led very important projects in this institution, such as the one reported in this paper. Mr. Hugo Hernández has been also a champion of metrology education and, after his experience in CENAM, he is now director of the company Metrology School which has innovative training-learning methods and is providing much for metrology education in Mexico. CENAM works with a variety of education and training providers such as UPSRJ, other universities, and The Metrology School (a private company) to expand the metrology impact within Mexico.

The contributions of these different perspectives created a very interesting kaleidoscope of inspiring images, all related to metrology education and training, mostly emphasizing the aspects of learning and development, as promoted by Ms. Georgia Harris for several years.

4.5. Immediate Benefits

For the group of students that attended the first two parts of the event, one immediate benefit is that they got tools for a better assessment of the role metrology plays in their research and development activities. After the event, they were given the homework of applying the discussed principles to their projects and they presented their essays the following week of the event. The results were very satisfying for them and useful for their projects.

For the group of metrologists-teachers that participated in the panel and the last session, one immediate benefit was a deep reflection on the techniques they are using to promote learning and development of competences, knowledge, skills, and attitudes in their trainees. They declared the ‘five best practices’ presented by Ms. Harris are a most useful tool to assess their teaching strategy and this will change their approach.

These best practices are described in section 2.7; but, in short they can be named:

1. Professionalize the instruction activity.
2. Align course design with methodology, learning objectives, activities and assessments.
3. Consider andragogy, the learning process of adults vs pedagogy, for children.
4. Apply ongoing evaluation of course design to remain current.
5. Professionalism and quality are better if accreditation of training programs is applied.

Some of the attendants immediately evaluated themselves in each of the best practices and are willing to address the points in which they are weak.

4.6. Expected Long-term benefits

For CENAM, the panel and the session about “five best practices” promoted an ongoing reflection about the role this Center must play in promoting learning and development in metrology in the whole country. The best practices must be followed, and a group is addressing this issue to define a strategy.

Another aspect being discussed is that of “Training Trainers”, that must go together with the construction of alliances and a network of instructors. The strategy to be defined must consider essential aspects of resources, logistics and the whole system to make it sustainable.

4.7. Lessons learned and insights gained

A main lesson learned from the collaboration described in this paper is that of open innovation. The interchange achieved with Ms. Harris and the different specialists from other organizations, UPSRJ, CENAM, Metrology School, UAQ, and secondary laboratories are, precisely, an example of open innovation regarding education and training in metrology. It is believed that this type of approach has great potential for further developments and this is being discussed in CENAM in its new strategic planning.

Another lesson is that very good results can be achieved by open collaboration among diverse institutions, sharing resources, work load, knowledge and experience. CENAM is grateful to the Fulbright Specialist Program, to NIST and the UPSRJ for having shared with us in this project.

5. Recommendations

Opportunities for international collaboration in metrology education and training can be sponsored and supported through various avenues, such as through the Fulbright Specialist program. University students from Mexico might apply to participate as Fulbright Scholars at NIST. Professional metrology instructors can apply to become Fulbright Specialists as a cost sharing mechanism. There are opportunities for U.S. technical experts to consider future collaboration using this mechanism. However, Fulbright Specialists (grantees) are restricted from receiving a grant more often than once every two years.

Regardless of funding sources, much can be gained from international collaboration in metrology education. Lessons learned and insights can enable improved international uniformity in

professional metrology education, training, and understanding for the entire metrology community. In general, fewer resources are applied to metrology education and training than technical research and realization of measurements, so those with an interest and passion in educational subjects can and should share ideas and resources to make a difference for the next generation. Projects between the Fulbright Specialist and UPSRJ and CENAM on developing supporting materials and publication references are also being pursued.

Future opportunities to measure the impact of international collaboration should also be considered. Developing published case studies that demonstrate the impact and benefit of international collaboration, metrology education and training, and metrology outreach can help support and defend the need and impact of ongoing efforts on these topics.

Disclaimer

Certain commercial products are identified in this paper to foster understanding. Such identification does not imply recommendation by the National Institute of Standards and Technology, nor does it imply that the products identified are necessarily the best available for the purpose.